

QTE Tag Controller Demo Manual

Overview

This demo application showcases the use of Quoppa Tag Emulation stack with custom state machine. Each state is features different advertising profile and is individually configurable over the Back Channel.

Hardware Requirements

This demo is compatible with the following hardware platforms:

- **RSL10 Evaluation Board**
 - Button and deep sleep wake-up feature is available on DIO0 pad. DIO0 needs to be connected to GND to simulate button press or wake-up event.
- **SECO-RSL10-TAG-GEVB board**
 - Battery holder is used as push button after battery is inserted and can be used to trigger button events.

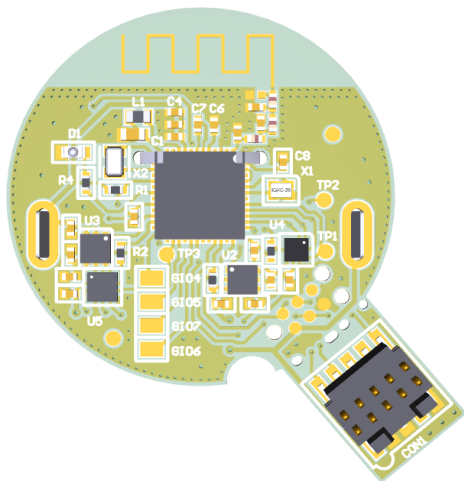


Figure 1 SECO-RSL10-TAG-GEVB board

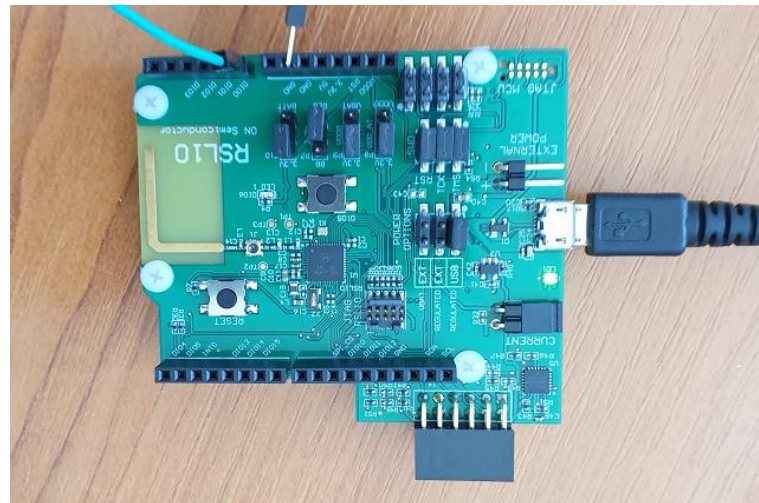


Figure 2 RSL10 Evaluation Board with jumper cable on DIO0 pad.

If demo application is compiled from source code then corresponding DIO pin map needs to be selected in the project from the configuration header file.

Tag behavior:

1. After power supply is provided (battery insertion or USB cable) the board will blink LED 5 times to indicate successful startup.
2. Afterwards the board will enter into Standby state starts transmitting Direction Finding packets with 0.5 Hz TX rate.
3. Data packet is transmitted after every 6 Direction Finding packet transmissions.
 - By default 3 Data Packet payloads are enabled (Device Info payload, custom State Configuration payload and fixed test pattern payload).
 - The firmware continuously cycles between all enabled payloads, effectively reducing the transmit rate of each payload type.
4. A Back Channel RX ON event occurs after every 5 Direction Finding packet transmissions (independent from Data Packets).
 - If a request is received during RX ON event then firmware immediately transmits 3 response packets with 100 ms spacing between responses.
5. Button can be used to modify tag behavior:
 1. Short press (< 3 seconds) - Switches tag to Triggered mode for 1 minute with 4 Hz TX Rate, Data Packet rate and Data Packet payloads. LED toggles in this mode every 2 seconds.
 2. Long press (>= 3 seconds) - Tag switches into storage mode after button is released. Tag will resume from storage mode on next button press. Custom tag configuration set over Back Channel is not preserved after return from Storage state.

Detailed Functional Description

Operation Modes

This application implements state machine with the following 5 operation modes:

1. **Triggered mode**
High duty cycle advertising mode entered when external interrupt is received. The source of external interrupt is usually an accelerometer that has detected motion and therefore tag increases advertising rate to improve localization quality for moving targets.
2. **Standby mode**
Low duty advertising mode typically used to report position of a stationary tag or to report that tag is alive after longer inactivity period if tag remained stationary for longer periods of time.
3. **Idle mode**
Low power mode with no advertising. In this mode the tag is not reporting position due to the tag not moving. The tag is still active and may quickly enter into Standby or Triggered modes on demand.
Implemented only as a workaround for boards with no accelerometer that do not have the necessary external wake-up trigger for motion events.
4. **Storage mode**
Power down mode with no advertising. In this mode only the external wake-up logic is powered and device is effectively restarted upon wake-up. This mode has lowest power consumption and can be used for prolonged storage.
5. **Command mode**
This mode can be entered only after a Back Channel request with special command payload is received. This mode can be used to temporarily change the tag behavior based on inputs from QPE.

The default state diagram of this application with all possible transitions is shown in Figure 1.

For the RSL10 Evaluation Board the transitions between different operation modes are triggered by one of the following conditions:

- *button_pressed* - High to Low transition on DIO0 pad.
- *button_pressed_long* - DIO0 pad held low for more than 3 seconds.
- *mode_timeout* - Automatic mode switch after configured inactivity period.
- *external_wakeup* - High to Low transition on DIO0 pad.
- *back channel request* - Any state can be entered based on State Configuration Write request from any state that actively listens for requests.

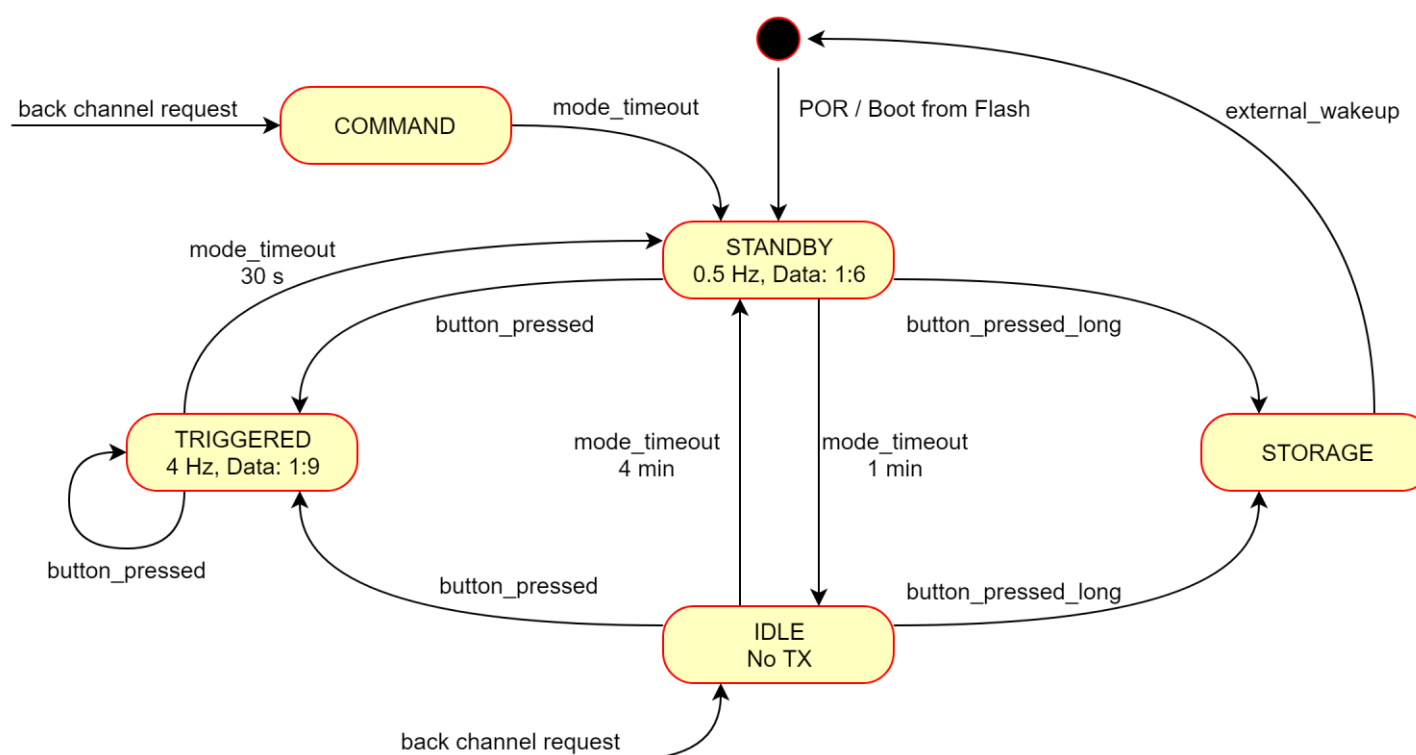


Figure 3. State machine implemented in the pre-flashed demo boards. States display Direction Finding TX Rate and Ration between Data packets and Direction Finding packets.

Configuration

The project is configured and can be recognized by QPE localization systems on **2402 MHz (BLE 37) RF channel**.

The tags use their factory loaded Public Bluetooth MAC address as unique Tag ID.

The Tags use the **Developer ID** of **0x0000** for all Developer Specific packets.

By default the tag uses **0 dBm TX Power** level for all operation modes.

Data Packets

Data packets are transmitted periodically after certain number of Direction Finding packets was transmitted. The number of Direction Finding packets between data transmissions is configurable for each operation mode.

The application can transmit different types of data packets including device info and developer specific packets. Each operation mode can be configured to transmit only certain subset of data packet types supported by the application.

This application supports the transmission of the following types of data packets:

- **Device Info payload**
Reports current Battery Voltage, Battery Alarm and Button 1 press events.
- **State Configuration Read payload**
Reports device configuration of currently active operation mode. The payload structure is identical to State Configuration Read response payload.
- **Test Pattern 1**
- **Test Pattern 2**
Fixed test patters. Can be replaced with other application specific payloads.
Not enabled by default but can be enabled via Back Channel request for testing.

Table 1: Default Data Packet configuration for each operation mode.

Operation Mode	Default Data Packet Ratio	Enabled Data Packet Types
Triggered mode	1:9	Device Info
Standby mode	1:6	Device Info, State Configuration
Idle mode	N/A	N/A
Storage mode	N/A	N/A
Command mode	1:8	Device Info

Back Channel Support

The sample code accepts Back Channel requests in Triggered, Standby and Command modes.

Operation Mode	Default RX ON event Ratio
Triggered mode	1:5
Standby mode	1:5
Idle mode	N/A
Storage mode	N/A
Command mode	1:5

The application accepts the following types of requests:

- **Device Info request**
- **Back Channel Info request**
- **State Configuration Write request**
Allows to reconfigure tag behavior in any state.
Not all operation modes allow to configure all available parameters.
- **State Configuration Read request**
Allows to read current configuration of any operation mode.

See Configuration Exchange Payloads section for more details and payload examples.

State Configuration Write Request (SCW)

The following configuration parameters are supported by the application:

- **Set TX Rate** - Configurable from 50 Hz (10 Hz for BLE 37 radio channel) to 0.10 Hz.
- **Set TX Power** - Configurable to -17, -12, -6, 0 or 3 dBm.
- **Set Data Packet types and frequency** Enable up to 4 different types of data packets.
- **Set Back Channel RX ON event frequency**
- **Set State Timeout** Determines how long to stay in a specific operation mode before switching to next mode according to the implemented state machine.
- **Set IO Configuration (LED)** IO Configuration 0 is mapped to on-board LED with the following operation modes:
 - Permanently OFF
 - Permanently ON
 - ON while RSL10 is awake.
 - Blink with configured period (default 2000 ms).

Not all parameters can be configured for all operation modes due to their different roles.

Table 2: List of configurable parameters for each operation mode using State Configuration Write request

Setting	Allowed values	Command	Triggered	Standby	Idle	Storage
Transmit rate	14 presets based on Quoppa	Yes	Yes	Yes	No	No
Response mode	Sets count of DF packets between RX ON events. 1 - 255	Yes	Yes	Yes	No	No
Transmit power	Select from: Minimal (-17 dBm), -12, -6, 0, 6 dBm	Yes	Yes	Yes	No	No
State timeout	13 values in range from 4 seconds to 24 hours	Yes	Yes	Yes	Yes	No
Enable Data packet payloads	Device Info on/off, Developer specific on/off Also sets ratio of Data packets	Yes	Yes	Yes	No	No
Accelerometer data rate	N/A, no accelerometer on EVK	No	No	No	No	No
Accelerometer trigger sensitivity	N/A, no accelerometer on EVK	No	No	No	No	No
Accelerometer range	N/A, no accelerometer on EVK	No	No	No	No	No
IO settings	1 IO output with states: On, Off, Blink Active, Blink Slow	Yes	Yes	Yes	No	No

SCW Request usage examples

All example payloads listed below use the default Developer ID of 0x0000.

Update base Tx rate of the device:

- FF 00 00 A3 00 30 40 00 00 00 00 00 00 - Set Tx rate for Triggered mode to 9 Hz / 111 ms
- FF 00 00 A3 00 70 40 00 00 00 00 00 00 - Set Tx rate for Triggered mode to 2 Hz / 500 ms (default)
- FF 00 00 A3 00 80 40 00 00 00 00 00 00 - Set Tx rate for Triggered mode to 1 Hz / 1000 ms
- FF 00 00 A3 00 B0 40 00 00 00 00 00 00 - Set Tx rate for Triggered mode to 0.25 Hz / 4000 ms
- FF 00 00 A3 00 B1 40 00 00 00 00 00 00 - Set Tx rate for Standby mode to 0.25 Hz / 4000 ms

Change Tx power level:

- FF 00 00 A3 00 00 20 00 00 00 00 00 00 - Set Tx power for Triggered mode to -17 dBm
- FF 00 00 A3 00 00 20 01 00 00 00 00 00 - Set Tx power for Triggered mode to -12 dBm
- FF 00 00 A3 00 00 20 02 00 00 00 00 00 - Set Tx power for Triggered mode to -6 dBm
- FF 00 00 A3 00 00 20 03 00 00 00 00 00 - Set Tx power for Triggered mode to 0 dBm
- FF 00 00 A3 00 01 20 03 00 00 00 00 00 - Set Tx power for Standby mode to 0 dBm

Change State Timeout:

- FF 00 00 A3 00 00 08 30 00 00 00 00 00 - Set State Timeout for Triggered mode to 20 seconds.
- FF 00 00 A3 00 01 08 50 00 00 00 00 00 - Set State Timeout for Standby mode to 1 minute.
- FF 00 00 A3 00 01 08 A0 00 00 00 00 00 - Set State Timeout for Standby mode to 2 hours.
- FF 00 00 A3 00 02 08 70 00 00 00 00 00 - Set State Timeout for Idle mode to 10 minutes.

Change Data Packet configuration:

- FF 00 00 A3 00 00 02 00 00 15 00 00 00 - Enable only Device Info data packets in Triggered mode. Transmit Data Packet after each 5th Direction Finding Packet.

- FF 00 00 A3 00 01 02 00 00 F6 00 00 00 - Enable all data packet types in Standby mode. Transmit Data Packet after each 6th Direction Finding Packet.

Update IO configuration 0 to change LED state:

- FF 00 00 A3 00 00 01 00 00 00 00 00 00 - LED is always off in Triggered Mode
- FF 00 00 A3 00 00 01 00 00 00 01 00 00 - LED is always on in Triggered Mode
- FF 00 00 A3 00 00 01 00 00 00 02 00 00 - LED is on while device is active (i.e. not in sleep mode) in Triggered Mode
- FF 00 00 A3 00 00 01 00 00 00 03 00 00 - LED toggles periodically every 2 seconds in Triggered Mode

Combined request example:

- FF 00 00 A3 00 30 73 02 08 15 02 00 00 - Set multiple parameters in the same request according to set Feature Flags:
 - Set configuration of Triggered mode
 - Set TX rate to 9 Hz
 - Set Tx Power to -6 dBm
 - Set RX ON event frequency to every 8 DF packets
 - Set Data Packet frequency to every 4 DF packets
 - Transmit only Device Info data packets
 - LED is on while device is active
- FF 00 00 A3 00 3C 73 32 08 15 03 00 00 - Switch to Command mode with the following configuration:
 - Set configuration of Command mode
 - Request operation mode change to Command mode
 - Set State Timeout to 20 seconds
 - Set TX rate to 9 Hz
 - Set Tx Power to -6 dBm
 - Set RX ON event frequency to every 8 DF packets
 - Set Data Packet frequency to every 4 DF packets
 - Transmit only Device Info data packets
 - LED is blinking every 2 seconds

Example response payloads:

- FF 00 00 A3 00 11 00 - This is the expected response payload when request is accepted without errors. Device was in Standby mode when request was received and remained in Standby mode after processing.
- FF 00 00 A3 00 41 00 - Same as above but device indicates switch from Standby mode to Command mode.
- FF 00 00 A3 00 08 00 - Request rejected due to generic error or invalid state ID. Device was in Triggered mode when request was received.
- FF 00 00 A3 00 11 40 - Request rejected due to invalid TX rate value. Device was in and remained in Standby state.

State Configuration Read Request (SCR)

This request can be used to read device configuration over back channel. The configuration parameters are equivalent to the State Configuration Write Request.

For full documentation and examples of this request refer to the documentation of `Device.Quuppa Tag Emulation.Configuration Exchange Payloads CMSIS-Pack` component.

SCR Request Usage example

Request current device configuration:

- FF 00 00 A4 00 00 - Request current configuration of Triggered mode
- FF 00 00 A4 00 01 - Request current configuration of Standby mode
- FF 00 00 A4 00 02 - Request current configuration of Idle mode
- FF 00 00 A4 00 04 - Request current configuration of Command mode

Possible response payload:

- FF 00 00 A4 00 50 7D 42 08 15 02 00 00 - This response corresponds to this configuration:
 - Configuration is associated with state ID: 0 (Triggered mode)
 - Reported / Configurable parameters for this state ID: Tx rate, Tx power, RX ON frequency, State Timeout, Data Packet configuration, IO configuration
 - TX rate: 250 ms / 4 Hz
 - State timeout: 30 seconds
 - Tx Power: -6 dBm
 - RX ON event frequency: every 8 DF packets
 - Data Packet frequency: every 4 DF packets
 - Enabled data packet types: Device Info only
 - LED is on while device is active

Configuration Exchange Payload Specification

This section describes payload structures of custom Developer Specific payloads that can be transmitted as Back Channel Requests or responses but also as Data Packet payloads.

State Configuration Write Request

This request can be send to the device over Quoppa Back Channel API in QPE to configure device behavior.

Single request can update one or more of available parameters of single device state and optionally force tag to switch to this state.

Some tag states might not accept all types of parameters.

If any errors are detected on device side when processing request then corresponding error flag will be set in the response and tag state will remain unchanged.

Request Payload Structure

Byte	Field	Bit							
		7 (MSB)	6	5	4	3	2	1	0 (LSB)
0	Request Type	req_type [7:0] = 0xFF							
1	Developer ID	developer_id [15:8]							
2	Developer ID	developer_id [7:0]							
3	Command Type	cmd_type [7:0] = 0xA3							
4	Version	version [7:0] = 0x00							
5	Timeout & State ID	tx_rate [3:0]			change_state		state_id[2:0]		
6	Feature Flags	RFU	set_tx_rate	set_tx_power	set_response_mode	set_state_timeout	set_acc	set_data_en	set_io
7	Transmit Power & Timeout	state_timeout [3:0]			write_to_storage		tx_power [2:0]		
8	Response mode	rx_on_interval [7:0]							
9	Data Payloads	develop_2_en	develop_1_en	develop_0_en	dev_info_en	dp_interval [3:0]			
10	IO Configuration	io_config_3 [1:0]		io_config_2 [1:0]		io_config_1 [1:0]		io_config_0 [1:0]	
11	Accelerometer Settings	RFU	RFU	acc_range [1:0]		RFU	RFU	acc_data_rate [1:0]	
12	Trigger Settings	trigger_sensitivity [7:0]							

Bytes 13 .. 15 of the payload are unused. If transmitted they shall be set to zero.

Field Description

- **req_type** [7:0] - Fixed value 0xFF for Developer Data Request Payloads
- **developer_id** [15:0] - Developer ID of the tag. Requests with invalid developer ID will be ignored.
- **cmd_type** [7:0] - Fixed value to identify type of Developer Payload. Set to 0xA3 for State Configuration Write Request payload.
- **version** [7:0] - Fixed value identifying the version of the State Configuration Request payload.
- **change_state** - If set the tag will switch into state set by **state_id** immediately after this request is processed.
- **state_id** [2:0] - ID of the state that is to be configured / switched to. State IDs are application specific.
- **set_tx_rate** - If set modifies Transmit Rate of the tag based on value of **tx_rate** value.
- **set_tx_power** - If set modifies Transmit Power of the tag based on **tx_power** value.
- **set_response_mode** - If set modifies RX ON event interval based on **rx_on_interval** value.
- **set_state_timeout** - If set modifies State Timeout Value based on **state_timeout** value.
- **set_acc** - If set modifies accelerometer settings based on **acc_range**, **acc_data_rate** and **trigger_sensitivity** values.
- **set_data_en** - If set modifies frequency and types of enabled data packets based on **payload_N_on** and **dp_interval** values.
- **set_io** - If set modifies configuration of IO pins to desired state based on **io_config_N** values.
- **write_to_storage** - Request to save updated state configuration into non-volatile memory of the device to be used as default state configuration after power cycle.
- **develop_N_en** - Enable transmission of Developer Specific Data Packets. Payload format is defined by application.
- **dev_info_en** - Enable transmission of Device Info Data Packets.
- **RFU** - All RFU bits are unused and shall be set to 0.

tx_rate [7:0]

Sets the advertising interval of Direction Finding Packets.

tx_rate	Advertising Interval	tx_rate	Advertising Interval
0	20 ms (50 Hz)	8	1000 ms (1 Hz)
1	30 ms (33 Hz)	9	2000 ms (0.5 Hz)
2	60 ms (17 Hz)	10	3000 ms (0.33 Hz)
3	111 ms (9 Hz)	11	4000 ms (0.25 Hz)
4	200 ms (5 Hz)	12	5000 ms (0.20 Hz)
5	250 ms (4 Hz)	13	10000 ms (0.10 Hz)
6	333 ms (3 Hz)	14	RFU
7	500 ms (2 Hz)	15	RFU

state_timeout [3:0]

Configures how long to remain in current state before switching to next state as defined by devices state machine.

state_timeout	Timeout	state_timeout	Timeout
0	Infinite	8	30 min
1	4 s	9	1 h
1	10 s	10	2 h
3	20 s	11	4 h
4	30 s	12	8 h
5	1 min	13	24 h
6	5 min	14	RFU
7	10 min	15	RFU

tx_power [2:0]

Configures TX power level of the device while in this state.

tx_power	TX Power Level
0	Minimal (-17 dBm for RSL10)
1	-12 dBm
2	-6 dBm
3	0 dBm
4	3 dBm
5 .. 7	RFU

rx_on_interval [7:0]

Determines how many Direction Finding packets are transmitted between two RX ON events when device listens for incoming requests.

rx_on_interval	Number of DF packets
0	RFU
1 .. 255	1 .. 255

dp_interval [3:0]

Determines how many Direction Finding packets are transmitted between two Data Packet transmissions.

If more than one type of Data packets is enabled in a given state (dev_info_en, develop_0_en, ..) then allocated data packet transmissions are equally split between all enabled data packet types.



dp_interval	Number of DF packets
0	RFU
1 .. 15	1 .. 15

io_config_N [1:0]

Sets the behavior of configurable DIO pads of the tag.

The precise blinking frequency is dependent on configured tx_rate as device is most likely able to update its DIO configuration only during/near advertising events.

io_config_N	IO Function	Description
0	Off	DIO is permanently held low.
1	On	DIO is permanently held high.
2	Blink Fast	DIO is toggled on every packet transmission event.
3	Blink Slow	DIO is toggled approx. every 2 seconds.

acc_range [1:0]

Sets the range of the accelerometer sensor.

acc_range	Accelerometer Range
0	±2g
1	±4g
2	±8g
3	±16g

acc_data_rate [1:0]

Sets sample rate of the accelerometer sensor.

acc_data_rate	Accelerometer Sampling Rate
0	Off
1	10 Hz
2	25 Hz
3	50 Hz

trigger_sensitivity [7:0]

Configures accelerometer trigger threshold to configure sensitivity of the device.

trigger_sensitivity	
0	Disabled
1	Highest sensitivity
255	Lowest Sensitivity

State Configuration Write Response

This Developer Specific Response payload is send for every State Configuration Command received by the device.

It's main purpose is to acknowledge new configuration and inform QPE in case of any configuration errors.

Response Payload Structure

Byte	Field	Bit							
		7 (MSB)	6	5	4	3	2	1	0 (LSB)
0	Response Type	rsp_type [7:0] = 0xFF							
1	Developer ID	developer_id [15:8]							
2	Developer ID	developer_id [7:0]							
3	Command Type	cmd_type [7:0] = 0xA3							
4	Version	version [7:0] = 0x00							
5	Timeout & State ID	RFU	state_id_new[2:0]			invalid_state_id	state_id[2:0]		
6	Error Flags	RFU	tx_rate_err	tx_power_err	response_mode_err	state_timeout_err	acc_err	data_en_err	io_err

Bytes 7 .. 15 of the response payload are unused and if are transmitted shall be set to 0.

Field Description

- **rsp_type** [7:0] - Fixed value 0xFF for Developer Data Response Payloads.
- **developer_id** [15:0] - Developer ID of the tag.
- **cmd_type** [7:0] - Fixed value to identify type of Developer Payload. Set to 0xA3 for State Configuration Write Response payload.
- **version** [7:0] - Fixed value identifying the version of the State Configuration Response payload.
- **changed_state** - If set the tag has acknowledged requested state change and will automatically change state after all Response packets are transmitted.
- **state_id_new** [2:0] - State ID of tag state that will be in effect after all RSP packets are transmitted.
- **invalid_state_id** - If set then the requested state_id does not exist in given device and all other data contained in the packet should be treated as invalid and not used.
Can be also used to indicate that the request was rejected for any other reason that is not specified by the error flags.
- **state_id** [2:0] - ID of the current tag state. This is tag state before any request triggered state transition. Informs of previous tag state.
- **x_err** - If given error flag is set then the request contained invalid configuration value for given tag state. If any of the error bit is set then the request was **rejected** and tag state is left **unchanged**.
- **RFU** - All RFU bits are unused and shall be set to 0.

State Configuration Read Request

This request can be used to read current configuration of a single device state.

Request Payload Structure

Byte	Field	Bit							
		7 (MSB)	6	5	4	3	2	1	0 (LSB)
0	Response Type	req_type [7:0] = 0xFF							
1	Developer ID	developer_id [15:8]							
2	Developer ID	developer_id [7:0]							
3	Command Type	cmd_type [7:0] = 0xA4							
4	Version	version [7:0] = 0x00							
5		RFU	RFU	RFU	RFU	RFU	RFU	state_id [2:0]	

Bytes 5 .. 15 of the request payload are unused and if are transmitted shall be set to 0.

Field Description

- **req_type** [7:0] - Fixed value 0xFF for Developer Data Request Payloads
- **developer_id** [15:0] - Developer ID of the tag. Requests with invalid developer ID will be ignored.

- **cmd_type** [7:0] - Fixed value to identify type of Developer Payload. Set to 0xA4 for State Configuration Read Request payload.
- **state_id** [2:0] - Requests to read configuration of a given device state. State IDs are application specific.
- **RFU** - All RFU bits are unused and shall be set to 0.

State Configuration Read Response

This Response payload is transmitted by the Direction For each State Configuration Read request.

It contains full configuration of a tag state specified by the `state_id` field of the request.

Response Payload Structure

Byte	Field	Bit							
		7 (MSB)	6	5	4	3	2	1	0 (LSB)
0	Request Type	rsp_type [7:0] = 0xFF							
1	Developer ID	developer_id [15:8]							
2	Developer ID	developer_id [7:0]							
3	Command Type	cmd_type [7:0] = 0xA4							
4	Version	version [7:0] = 0x00							
5	Timeout & State ID	tx_rate [3:0]				invalid_state_id	state_id[2:0]		
6	Feature Flags	RFU	set_tx_rate	set_tx_power	set_response_mode	set_state_timeout	set_acc	set_data_en	set_io
7	Transmit Power & Timeout	state_timeout [3:0]				RFU	tx_power [2:0]		
8	Response mode	rx_on_interval [7:0]							
9	Data Payloads	develop_2_en	develop_1_en	develop_0_en	dev_info_en	dp_interval [3:0]			
10	IO Configuration	io_config_3 [1:0]		io_config_2 [1:0]		io_config_1 [1:0]		io_config_0 [1:0]	
11	Accelerometer Settings	RFU	RFU	acc_range [1:0]		RFU	RFU	acc_data_rate [1:0]	
12	Trigger Settings	trigger_sensitivity [7:0]							

Bytes 13 .. 15 of the payload are unused. If transmitted they shall be set to zero.

Field Description

- **state_id** [2:0] - Identifies the state this configuration belongs to.
- **invalid_state_id** - If set then the requested `state_id` does not exist in given device and all other data contained in the packet should be treated as invalid and not used.

All flags in the **Feature Flags** byte indicate which configuration parameters are available in this state.

If given flag is set to 0 then the associated values shall be ignored and the device will not accept these parameters when attempting to use State Configuration Write request.

All **other fields** use the same value format as their counterparts in the State Configuration Write Request payload.