BT IO
Functional Description

BT IO

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1 Scope

1.1 Identification

This document is the functional description for the Bluetooth IO product, referenced as document cBProject-0430-01.

The product is identified as cB-0719-02.

1.2 System Overview

The BT IO connects an IO using the wireless Bluetooth technology to a field bus. The field bus connection makes it possible for superior systems, i.e. a PLC, to communicate with the IO.

The BT IO product defines two roles in the system, the Bus Unit and the IO Unit:

- Scenario 1. The Bus Unit, which connects the wireless BT IO to the field bus and further on to the information acquiring system (PLC).
- Scenario 2. The IO Unit, which actuates the outputs and reads the inputs. Two IO units may also be used to form an IO-to-IO mirroring application, later called the Gateway option.

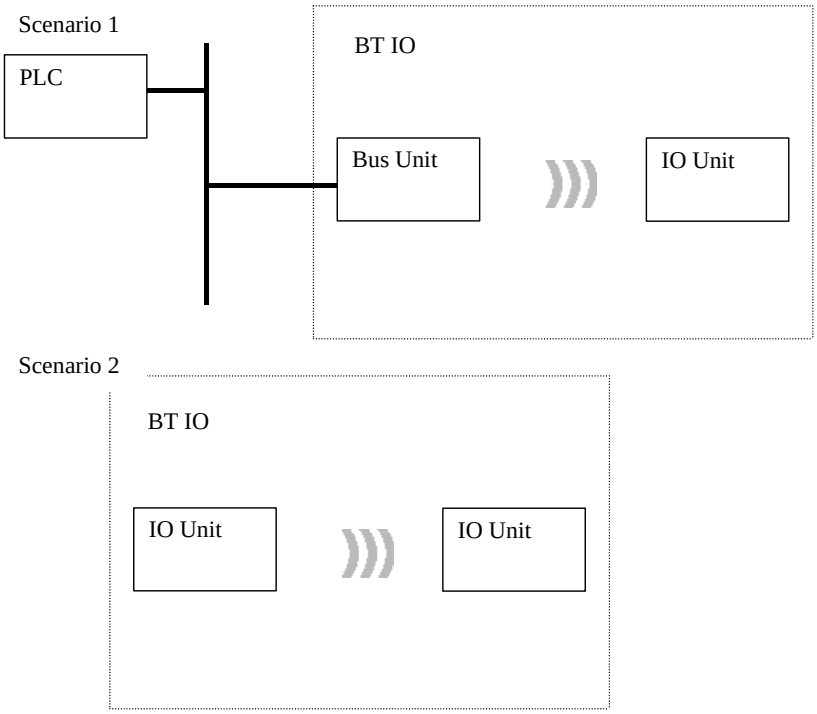


Figure 1 - Displays the system overview for the BT IO and its user scenarios

The system shall be easy to use and deploy and use standard protocols for increased interoperability and freedom of choice.

1.3 Document Overview

The document is divided into several parts. The first part discusses the functionality of the BT IO along with its hardware design. Part two addresses the functionality of system.

The intention is to divide the development project into several steps. What is included within in the different steps are marked with the following (within parentheses):

(1) **Basic 1**. Basic 1 indicates a basic SW functionality that may enhance the currently available prototype and may execute in the current prototype HW. This includes a limited simple multi-point support.

(2) **Basic 2**. Basic functionality including a new HW. This has limited latency requirements and no diagnostics functionality.

(3) **Step 2**. A second step with the goal to reach full functionality with advanced latency support, multi-point support and full diagnostics interface.

(4) **Robot**. Enhancement needed for the robot tool application only.

(5) **Gateway**. Optional functionality where to units can be connected mirroring the digital and analog IO over the Bluetooth link. Will only exist in a point-to-point version. This option requires Basic 1 and Basic 2.

(6) **Diagnostics**. A subset of the Step 2 functionality with support for diagnostics messages.

(7) **I2C Management**. Added functionality to support I2C management over the diagnostics/management interface.

Note! The current version of the documents focuses on the first steps of the project (Basic 1, Basic 2, Gateway, Diagnostics and I2C Management). For certain parts of the document there is descriptions for future parts as well but these parts shall not by now be considered as complete.

2 References

Reference	Description
1	Bluetooth HID Profile, Revision 1.0
2	Bluetooth Core Specification, Revision 1.2
3	RSSI, Link Quality and Out-of-Range Indication, Application Note, July 2002
4	RAD-ISM-2400-ANT-PAN-8-0; antenna datasheet
5	RAD-ISM-2400-ANT-OMNI-2-1; antenna datasheet
6	RAD-ISM-2400-ANT-OMNI-9-0; antenna datasheet
7	WCR2400SMA, antenna datasheet
8	pstn-2400s-_500-308, antenna datasheet

3 Revision History

Version	Responsible	Description
1	Andreas Hörjel	Initial version
2	Mats Andersson	Modified after internal connectBlue revision
3	Mats Andersson	Modified after meeting in Malmö 7th April 2004
4	Mats Andersson	Added basic support for a multi-point use case not optimised for latency. Marked with *italic.*
5	Mats Andersson	Divided into steps. Functions (chapters) marked with the following: (1) Basic 1 = Support for the basic multipoint with low latency requirements. Executes on prototype HW. (2) Basic 2 = Full product with basic requirements and new HW. (3) Step 2 = Added full functionality. (4) Robot = Robot tool specific.
6	Mats Andersson	Updated + more detailed spec. of the diagnostics support. Mounting alternatives for short-range and long-range removed. All modules are long-range.
7	Andreas Hörjel/Mats Andersson	Updated + shift register data packet UART<->UART configuration and Channel id handshake.
8	Andreas Hörjel/Mats Andersson	First Update after project meeting 04.09.17. Remaining question is indicated by a bold, italic and red text comment. Added the Gateway option.
9	Mats Andersson	Update after review by Phoenix Contact. Revision of PIO usage. Use IO to indicate link quality and failsafe mode. Added support for a B-to-B connector. Revised messaging interface.
10	Mats Andersson	Added support for auto-pairing. Corrected errors in PIO pinning. No HW outline and changed pinning order.
11	Mats Andersson	Added support for diagnostics messages based on the list from Mr Fuhs.
12	Mats Andersson	Added support for I2C management over the UART interface.
13	Mats Andersson	Analog IO Voltage is 0 – 2.5 V not 0 – 1.8 V

		BER as a PWM output Added PSKEYS for the analog calibration feature. Added PSKEY for limiting of the output power to support hi-gain antennas. Added PSKEY for changing the Bluetooth Name Added type approved antennas.
14	Mats Andersson	Added support for connectBlue antennas More details about output power limitation. Added Regulatory Information chapter. Link quality indicator updates every 5 second Updated introduction. Block diagram added. Digital filterering.
15	Mats Andersson	Modified FCC Statement
16	Mats Andersson	Added STX in message structure for the data and diagnostics messages.
17	Mats Andersson	Modified power table settings.
18	Mats Andersson	Added an example of how to use max output power setting.
19	Mats Andersson	Additional items in the Regulatory chapter for IC compliance and safety.
20	Mats Andersson	Adding label and end user manual information and requirements.
21	Mats Andersson	Added a table showing the appropriate power settings to reach a maximum of 100 mW. Added new label positions.
22	Mats Andersson	Updated power table starting at 16dBm and 4 dBm steps. New levels for the link quality indicator. Byte order modified for the UART data message.
23	Mats Andersson	Synchronous UART protocol. Modified Regulatory chapter. Modified product name.

4 BT IO

4.1 Overview

The BT unit is a Bluetooth unit that is designed for sending of IO data and diagnostics information. The unit is designed with:

1. Both external and optionally an internal antenna.
2. Long-range (100 mW) radio.
3. UART, PIO, AIO, Power and I2C interface easily accessible from two different connector alternatives.

The unit is mounted on a motherboard using solder pads on the edges of the unit or from a one-piece part board-to-board connector. This makes the module easy to design in on the motherboard.

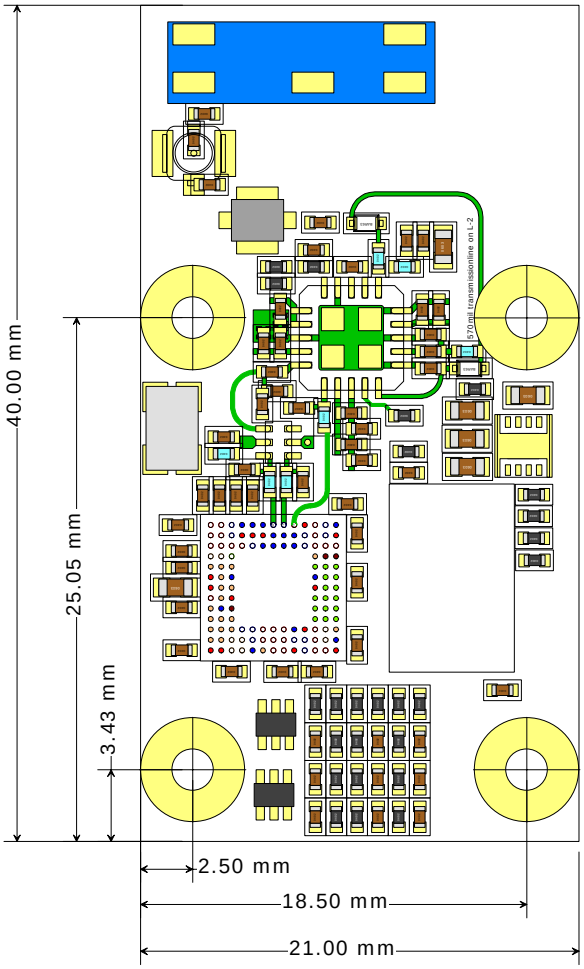


Figure 2 - Displays an overview of the BT unit

The hardware for the BT IO units is based on the CSR (**C**ambridge **S**ilicon **R**adio) BC03 MultiMedia module (BC03-MM) and equipped with an external Power Amplifier (PA) for the output and a Low Noise Amplifier (LNA) for the input.

BT IO Functional Description

4.2 Hardware (Basic 2)

4.2.1 Block Diagram

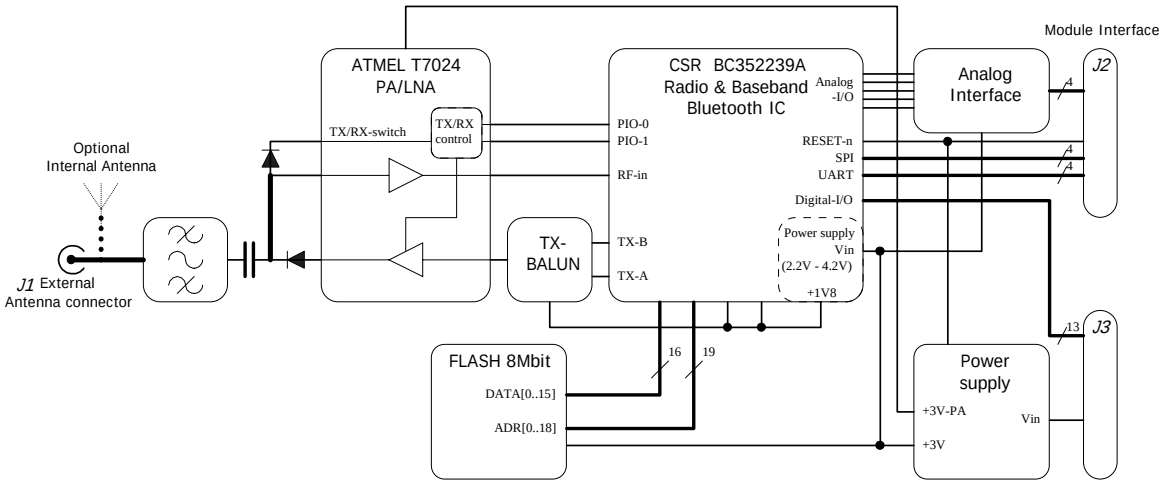


Figure 3 - HW Block Diagram

4.2.2 Basic Layout and Mechanical Design

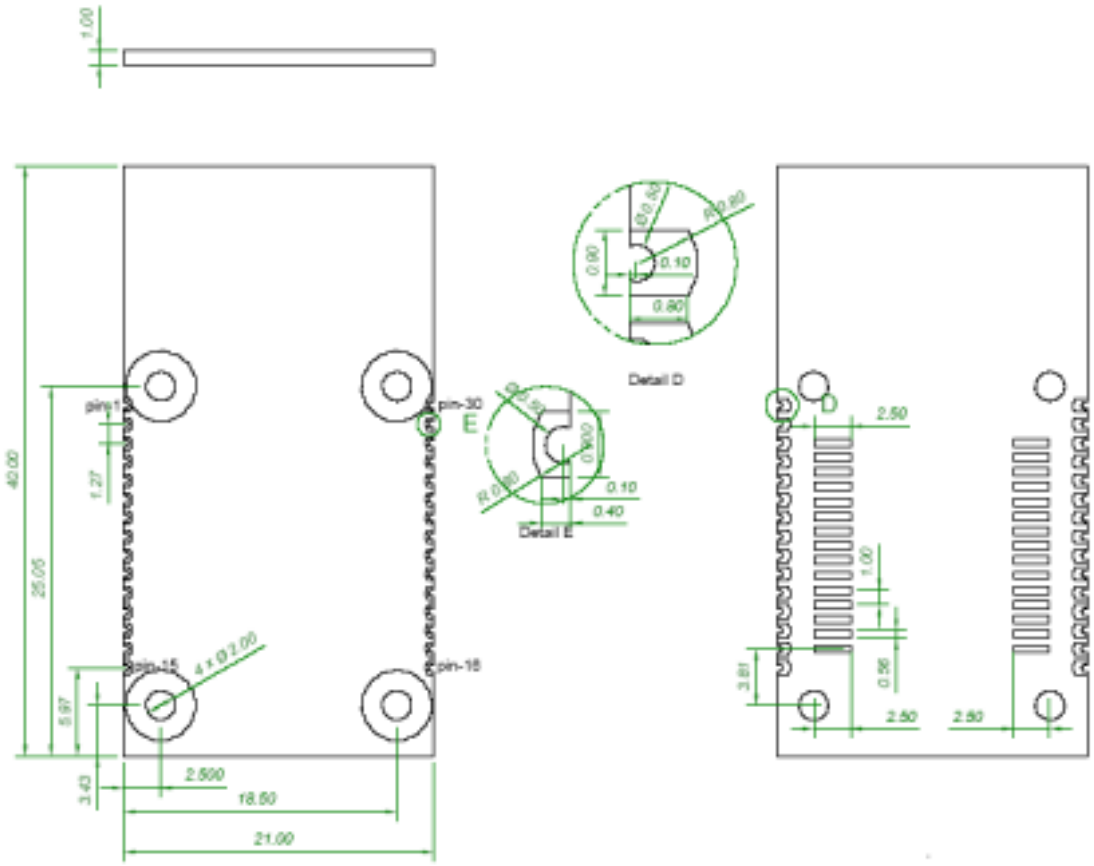


Figure 4 – PCB Outline

4.2.3 Electrical Interfaces

The BT unit exposes six interfaces that are used for communication e.g. for diagnostics, configuration and data communication purposes + an interface for an external antenna.

The standard antenna configuration is an UFL connector for an external antenna. The PCB is prepared for use with an internal antenna. .

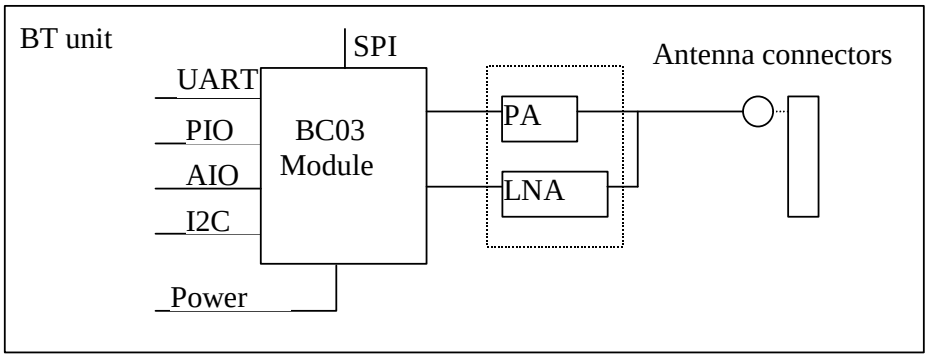


Figure 5 - Displays the all-possible interfaces of the BT unit.

The connection are available as soldering pads (see Figure 4) or at pads to be used by a Samtec board-to-board connector with the Samtec part number SEI-115-02-GF-S-M-TR. See Figure 6 for the pin numbering of the connector on the motherboard.

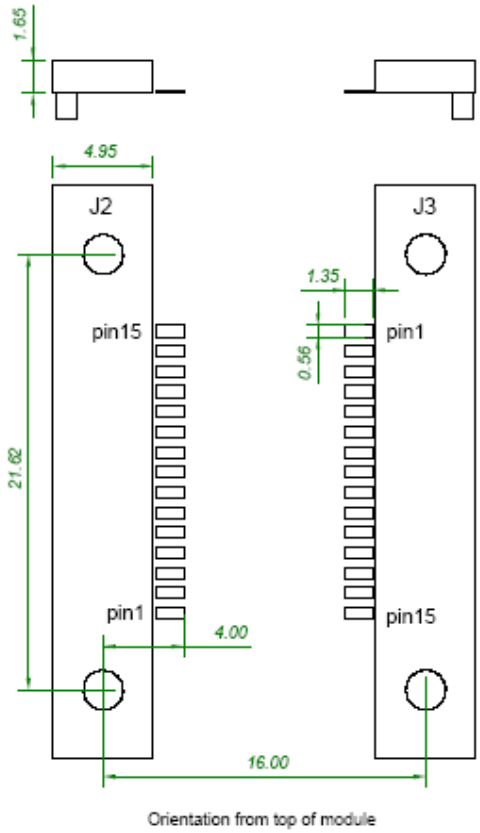


Figure 6 - Pinning of the Samtec connector on the motherboard

4.2.3.1 General Purpose I/O

All General Purpose IO are logic level 0V – 3.3V.
Maximum load on all GPIO are 4mA.

Module Pin nr.	Connector Terminal	Pin Name	Type	Description
28	J3-pin-3	DigIO-0	GPIO	Connected to PIO-2, bi-directional programmable pull-up/down
27	J3-pin-4	DigIO-1	GPIO	Connected to PIO-3, bi-directional programmable pull-up/down
26	J3-pin-5	DigIO-2	GPIO	Connected to PIO-4, bi-directional programmable pull-up/down
25	J3-pin-6	DigIO-3	GPIO	Connected to PIO-5, bi-directional programmable pull-up/down
24	J3-pin-7	DigIO-4	GPIO	Connected to PIO-6, I2C_SCL
23	J3-pin-8	DigIO-5	GPIO	Connected to PIO-7, I2C_SDA
22	J3-pin-9	DigIO-6	GPIO	Connected to PIO-8, I2C_WP-n
21	J3-pin-10	DigIO-7	GPIO	Connected to PIO-9, bi-directional programmable pull-up/down
20	J3-pin-11	DigIO-8	GPIO	Connected to PIO-10, bi-directional programmable pull-up/down
19	J3-pin-12	DigIO-9	GPIO	Connected to PIO-11, bi-directional programmable pull-up/down
18	J3-pin-13	AuxIO-0	AuxIO	Connected to AuxIO-0, 8-bit analog IO
17	J3-pin-14	AuxIO-1	AuxIO	Connected to AuxIO-1, selectable analog/digital-IO
16	J3-pin-15	AuxIO-2	AuxIO	Connected to AuxIO-3, selectable analog/digital-IO

General Purpose IO Use (used later in the document)	
Active	High (3.3 V)
Not Active	Low (0.0 V)

4.2.3.2 Analog-I/O

The analog input and outputs signal level is between 0 – 2.5V.
Use VSS-AIO as GND reference and return path.

Module Pin nr.	Connector Terminal	Pin Name	Type	Description
11	J2-pin-5	AnaOUT-2	Output	Connected to Audio-out-right
12	J2-pin-4	AnaOUT-1	Output	Connected to Audio-out-left
13	J2-pin-3	VSSAIO	Power	GND pin dedicated to Analog-IO
14	J2-pin-2	AnaIN-2	Input	Connected to Audio-in-right
15	J2-pin-1	AnaIN-1	Input	Connected to Audio-in-left

4.2.3.3 Logic level SPI-communication

Module Pin nr.	Connector Terminal	Pin Name	Type	Description	Level
6	J2-pin-10	SPI-MOSI	Input	SPI data input	0V/3V
7	J2-pin-9	SPI-Clk	Input	SPI clock input	0V/3V
8	J2-pin-8	SPI-CSB	Input	SPI Chip select, active low	0V/3V
9	J2-pin-7	SPI-MISO	Output	SPI Data output	0V/3V

10	J2-pin-6	Reset-n	Input	Module reset active low	0V/3V

Used for debugging, programming and reprogramming of the unit. It is highly recommended to have this connector accessible on the IO motherboard.

4.2.3.4 Logic level UART-communication

Module Pin nr.	Connector Terminal	Pin Name	Type	Description	Level
2	J2-pin-14	Rx	Input	Receive data	0V/3V
3	J2-pin-13	RTS	Output	Request to Send	0V/3V
4	J2-pin-12	Tx	Output	Transmit data	0V/3V
5	J2-pin-11	CTS	Input	Clear To Send	0V/3V

4.2.3.5 Logic level I^2C -communication

See section 4.2.3.1, General Purpose I/O.

4.2.3.6 Power connections

Module Pin nr.	Connector Terminal	Pin Name	Type	Description
1	J2-pin-15	VSS	Power	Module GND.
30	J3-pin-1	VSS	Power	Module GND.
29	J3-pin-2	+3.3V	Power	Module power supply voltage 3.3V -5% +10%

4.2.4 Antennas

The BT unit HW supports two different antenna configurations.

Types of Bluetooth antennas:

- External antenna connector.
- Internally mounted antenna (Optional)

An UFL connector is used for connecting of an external antenna. See Figure 2 for a picture how this is done.

4.2.5 Type approved antenna

The Type Approved antennas are:

Name	Comment
RAD-ISM-2400-ANT-PAN-8-0	8 dBi gain directional antenna. See reference 4.
RAD-ISM-2400-ANT-OMNI-2-1	9 dBi omni-directional antenna.

	See reference 5.
RAD-ISM-2400	2 dBi omni directional antenna. See reference 6.
PSTG0-2400HS	0 dBi omni directional quarter wave stub antenna. See reference 8.
WCR2400SMA	3 dBi Omni-directional antenna. See reference 7).

NOTE! To use the high gain antennas (higher than 2dBi), the maximum output power needs to be limited. The maximum allowed output power varies between regions and countries and needs to be checked before a specific antenna is used. An example:

A RAD-ISM-2400-ANT-PAN-8-0 antenna is used connected to cabling with 2 dB losses. The maximum output power allowed is 20 dB EIRP: The max output power is calculated like this:

MAX_TX_POWER = 20 (the limit) + 2 (cable losses) – 8 (maximum antenna gain).

This gives the value of 14 dB. See section 4.10.1 for information about how to set the value using a PSKEY called PSKEY_LC_MAX_TX_POWER.

The table below shows power settings for certain antenna assuming a zero cable loss:

Antenna Type	**PSKEY_LC_MAX_TX_POWER Value**
RAD-ISM-2400-ANT-PAN-8-0	12
RAD-ISM-2400-ANT-OMNI-2-1	12
RAD-ISM-2400	16 (the default value)
PSTG0-2400HS	16 (the default value)
WCR2400SMA	16 (the default value)

4.2.6 Temperature range

The operating temperature range of the BT units is -25°C to +85°C (with guaranteed radio performance).

4.2.7 Labels on the BT unit

The following two labels are attached on the module:

S/N:0719-02-xxxxx	CE connectBlue FCC ID PVH071902 IC: 5325A-0719X

The fist label includes an individual serial number. The second label contains regulatory information (e.g. FCC and IC id). For more information on regulatory issues see section 6).

The above label will be attached to the module, located as shown in the figure below:

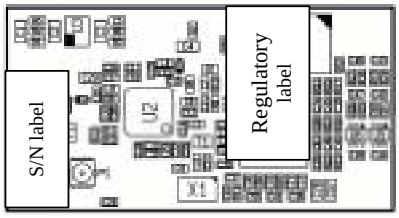


Figure 7 - Label positions

4.3 Bus Unit (Basic 2)

The Bus Unit communicates with the BT unit using an UART. The UART is used both for management/diagnostics and IO data information.

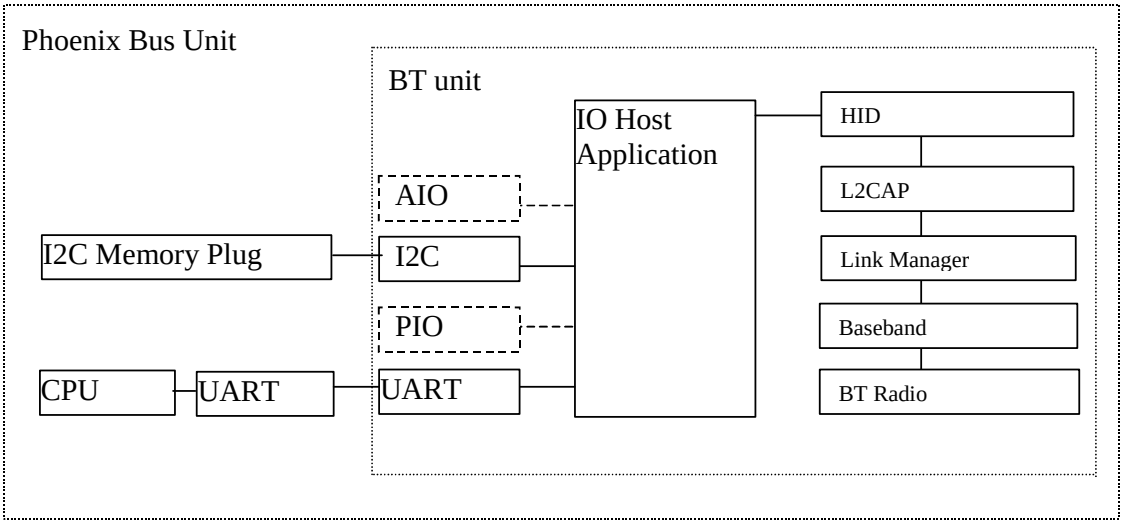


Figure 8 - Displays the hardware configuration of the Bus Unit. The dashed lines are optional sections not used in this configuration. The dotted lines describe the hardware separation line.

The I2C memory plug is used for configuration of the IO Units (see section 4.11.1).

4.3.1 UART Characteristics

Characteristic	Value
Baud rate	115 200 bits/s
Character width	8 bits
# of stop bits	1
Parity	Even

4.4 IO Unit (Basic 2)

The IO unit exists in two different hardware configurations.

4.4.1 Block IO

This configuration actuates and samples the IO and AIO, without the need for an external CPU.

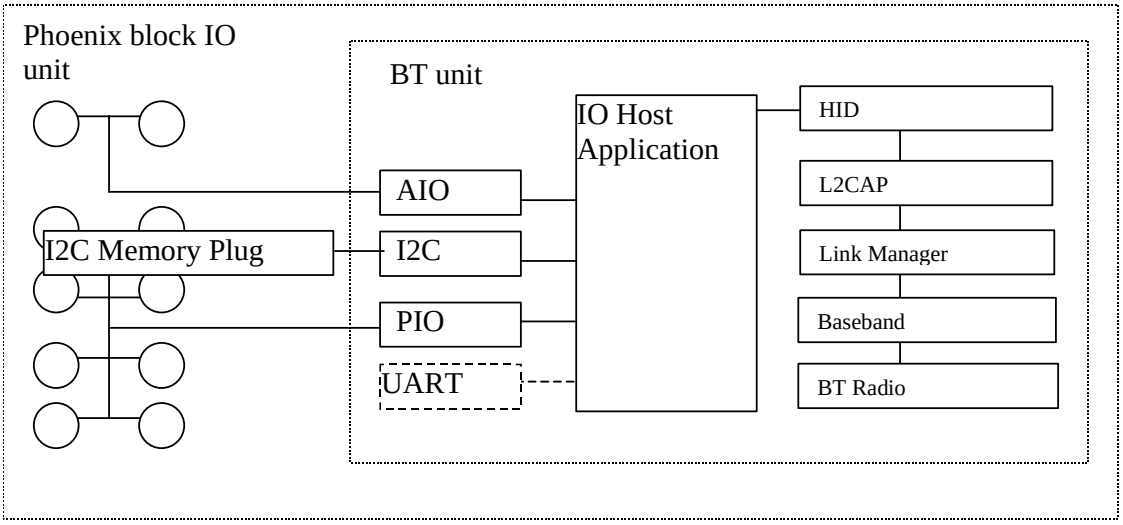


Figure 9 - Displays the hardware configuration of the Block IO Unit. The dashed lines are optional sections not used in this configuration. The dotted lines describe the hardware separation line.

The I2C memory plug is used for configuration of the IO Units (see section 4.11.1).

4.4.1.1 Digital IO Shift Register

The digital IOs for block IO are used for driving shift registers in order to expand the number of digital inputs and outputs. An example hardware solution is described below (not part of this project).

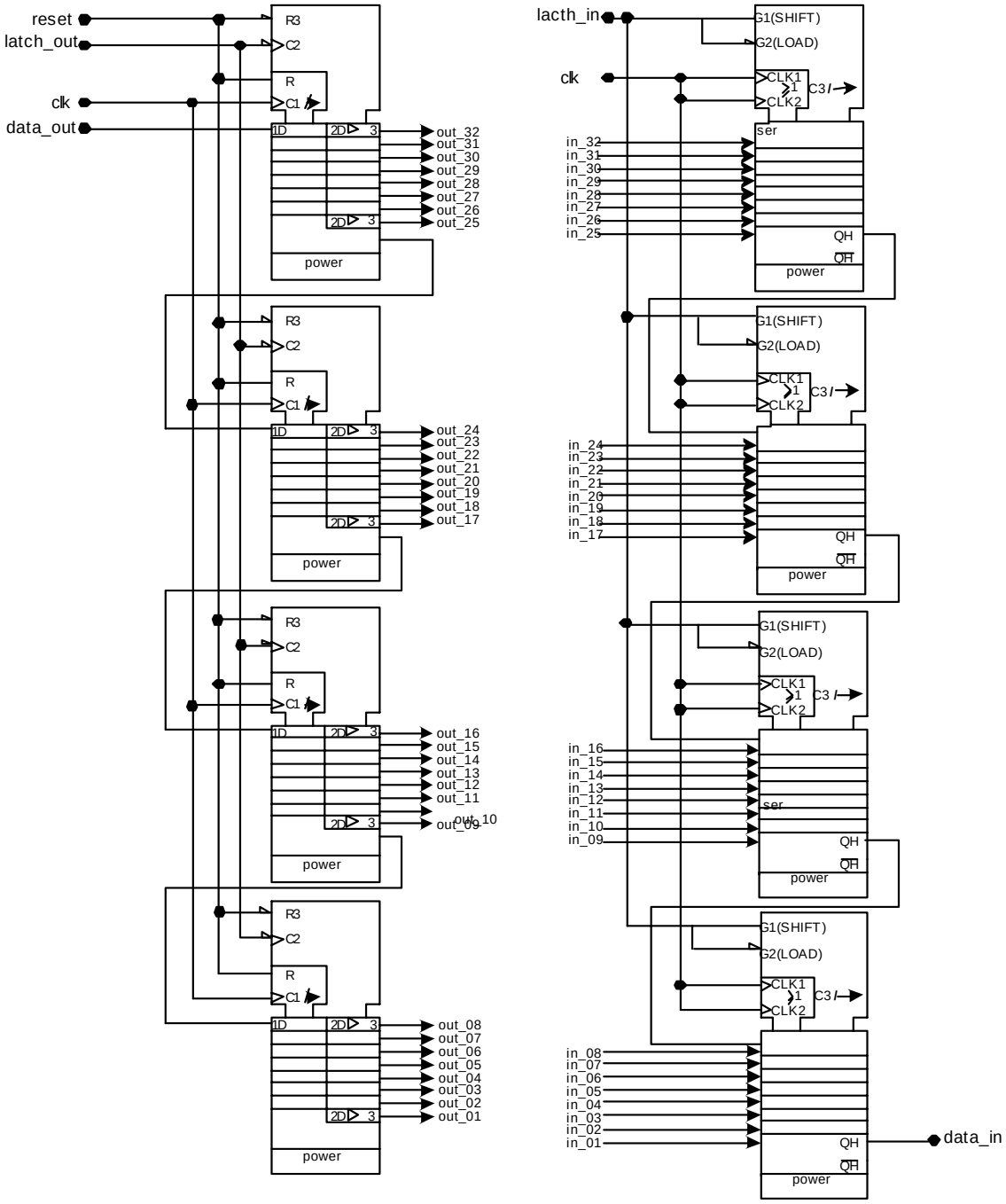


Figure 10 - An example of a shift register implementation

This solution has the following pin assignment:

PIO nr	PIO name	PIO properties
DigIO-0	Clk	10MHz output
DigIO-1	Data_out	10 Mhz output
DigIO-2	Data_in	10 MHz input
DigIO-3	Reset	Output
DigIO-7	Latch_in	Output
DigIO-8	Latch_out	Output

The PIO properties are given to fit the IO unit's possibilities to drive the PIO pins. This is especially important to notice if the signals shall be isolated using opto couplers. The 10 MHz value is an estimated value.

4.4.1.2 Digital IO – Filtering

A simple filtering is used for the digital IOs. The same value must be detected in two (2) consecutive readings for the value to be considered as valid.

4.4.1.3 Analog - IO Precision

The analog IO precision is 12 bits.

4.4.1.4 Analog IO – Anti-aliasing filter requirements

The preliminary sampling rate is 16 kHz. This means there is a need to have a filter (externally from the Bluetooth Units) that filters away components with higher sampling frequency than the sampling rate divided by 2 and with the required signal/noise ratio.

4.4.1.5 Analog IO - Input Filter

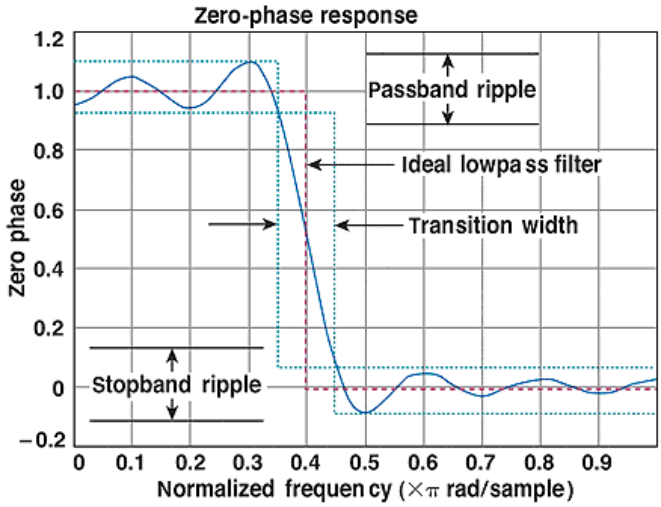
This section describes how the analog inputs of the Block IO shall be filtered. The outputs are set without any filtering. As described the BTIO units contains a DSP. This DSP can and be used for digital filtering of the input signal.

Possible filter is a low pass **F**inite **I**mpulse **R**esponse filter (FIR). The IO Unit can send an update of the analogue input with a frequency off 200 Hz, according to the HID sniff interval. However the DSP can sample the signal much faster, this will be done in order to get an accurate value.

The characteristics decided are:

Input filter	
Sampling frequency	>= 8Khz

Stop band ripple	<= 0,05%
Pass band ripple	<= 0,05%
Cut frequency	40 Hz
Phase delay	
Transition width	10 µs



1. This illustration shows the typical deviations from the ideal lowpass filter when approximating the response with an FIR filter, $\omega_c = 0.4\pi$.

Figure 11 - FIR filter

4.4.1.6 Analog IO – PSKEYS for the analog calibration

The PC runs a calibration program with access to certain PSKeys. A PSKey is a variable stored in flash, **P**ersistent **S**tore. These PSKeys is used to set the module in calibration mode, enables you to read the ADC values and the set the digital value to the DAC. These PSKey are used when calibrating the units.

NAME	PSKey name	Value
PS_TEST_AIO	PSKEY_USR1	Calibration mode = 1 run mode = 0
PS_VOUT	PSKEY_USR2	0 - 0xFFFF
PS_VIN1	PSKEY_USR3	0 - 0xFFFF
PS_VIN2	PSKEY_USR4	0 - 0xFFFF
PS_IN1_OFF	PSKEY_USR5	0 - 0xFFFF
PS_IN1_GAN	PSKEY_USR6	0 - 0xFFFFFF
PS_IN2_OFF	PSKEY_USR7	0 - 0xFFFF
PS_IN2_GAN	PSKEY_USR8	0 - 0xFFFFFF
PS_OUT1_OFF	PSKEY_USR9	0 - 0xFFFF

PS_OUT1_GAN	PSKEY_USR10	0 - 0xFFFFFF
PS_OUT2_OFF	PSKEY_USR11	0 - 0xFFFF
PS_OUT2_GAN	PSKEY_USR12	0 - 0xFFFFFF

PS_TEST_AIO is used for setting the module in calibration mode or run mode. The module will start in calibration mode if this PSKey is set to 1. PS_VOUT shall be used to set the digital value for the DAC, both of them. PS_VIN1 gives the read value from the ADC 1 and PS_VIN2 for ADC 2. The other PSKeys shall be used for when setting the new calibration for each ADC and DAC.

4.4.1.7 Gateway functionality (Gateway)

In this mode, two IO units operating in direct IO mode is interconnected as a pair. Digital Inputs are mirrored to Digital Outputs of the other unit and the other way round. The same with the analog IOs, they are mirrored in both directions.

4.4.2 Module IO

The module IO unit communicates with the BT unit using an UART. The UART is used both for management/diagnostics and IO data information. The BT unit communicates (over Bluetooth) all IO information and some of the management/diagnostics information to the Bus unit.

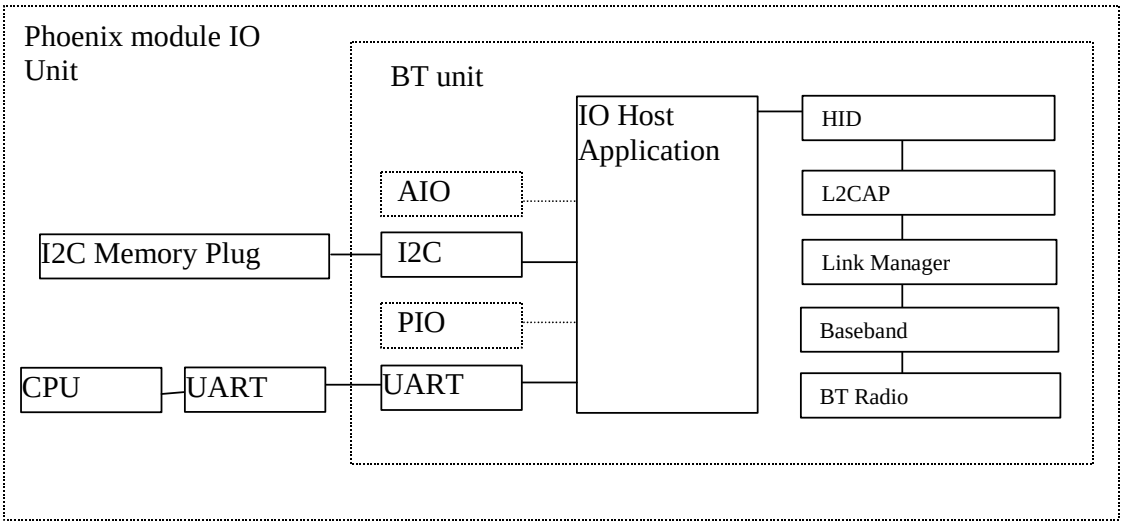


Figure 12 - Displays the hardware configuration of the Module IO unit. The dashed lines are optional sections not used in this configuration. The dotted lines describe the hardware separation line.

The I2C memory plug is used for configuration of the IO Units (see section 4.11.1).

4.4.2.1 UART characteristics

See section 4.3.1.

4.5 Common Bus and IO Unit functionality (Basic 2)

4.5.1 Link quality indication

The link quality measures the Bit Error Rate (BER) with following values. Between 0xff and 0xd7 each bit distance represents 0.00025 BER. Thus:

Link Quality Value		BER %
Dec	Hex	
255	0xff	0.0000
254	0xfe	0.0025
253	0xfd	0.0050
252	0xfc	0.0075
etc. until		
215	0xd7	0.1000

Between 0xd6 and 0x5a each bit distance represents 0.08 BER. Thus:

Link Quality Value		BER %
Dec	Hex	
215	0xd7	0.1000
214	0xd6	0.1800
213	0xd5	0.2600
etc. until		

Between 0x59 and 0x00 each bit distance represents 0.64% BER.

In general a BER between 0 and 0.1% is workable. When the link is broken the value will be set to 0.

The measurements are averaged, exponentially over a number of packages (between 5 and 20). In order to minimize performance impact the value is updated once every 5 second.

PIO nr	Description
AuxIO-0	Aux-signal used as digital Pulse Width Modulated (PWM) output. Used to indicate the link quality (value between 0-255). See below for a table of the values. The output are 4 values representing 25, 50, 75, 100% duty cycle respectively (for the BER values, see the table above): 100% => BER value between 235-255 75% => BER value between 215-234 50% => BER value between 195 - 214 25% => BER value < 195.

4.5.2 Fail-safe mode indication

PIO nr	Description
AuxIO-2	Aux-signal used as digital IO. Active indicates that the unit is in fail-safe mode.

4.5.3 Auto Pairing

Auto Pairing is used as method to pair two devices in a single-point configuration (see section 4.9 for the different supported configurations). This method is only usable when the I2C plug not is detected, see section 4.6.

Three PIOs are used to support this:

PIO nr	Description
DigIO-6	Input pin to set the unit in pairable/pairing mode respectively. The IO-unit is set to pairable and bus unit to pairing mode. NOTE! This pin is has two usages. This use and used as a write-protect pin when the I2C-plug is detected (see section 4.6).
Aux-IO-1	GREEN. The same LED as the GREEN LED used as I2C-indicator (see section 4.6). Will be set to Active at a successful pairing and not active at an un-successful pairing.

DigIO-9	RED. The same LED as the RED LED used as I2C-indicator (see section 4.6). Will be set to not active at a successful pairing and active at an un-successful pairing.

4.6 I2C Memory Plug (Basic 2)

This is a I2C connected memory. This unit is used to store information needed to set-up the virtual cable between the IO unit and the bus unit. It contains:

- Bus Unit Bluetooth address.
- Bus Unit Passkey
- Bus Position of the IO unit using the plug (I2C Management)

4.6.1 Functionality of the plug

The plug is used to identify the Bus Unit for an IO Unit. When an IO Unit is powered on the Bluetooth address and passkey is read and used to be able to connect to the Bus Unit.

The I2C plug has always the I2C member address '1010000'. (I2C Management)

When the plug is placed in the Bus Unit the Bluetooth Address and the passkey of the Bus Unit is written to the plug. A default Bus Position of 1 is written to the plug and an I2C Plug detection message is sent to the host (if it is a host based system). When a “Set Bus Position Request” management message is received the bus position contained in the message is written to the plug and the associated response message is sent to the host. For more on the messages used see chapter 4.10. (I2C Management)

The I2C Memory Plug is not developed as a part of this project..

4.6.2 User interface

The BT units detects if there is a unit present on the I2C bus by using the electrical characteristics of the I2C bus. This is done by looking at DIGIO-4 and DIGIO-5 PIO signals. If both are active the I2C Plug is considered as present.

Two of the BT Unit PIO pins are used as user interface LEDs on the IO motherboard. These pins are called Green and Red. Pin assignment:

PIO nr	PIO name
DigIO-9	RED
AuxIO-1	GREEN

The following behaviour:

Unit	Indicates	RED pin	GREEN pin
Bus Unit	Not connected	Not Active	Not Active
	Connected	Not Active	Active
	Connected and a successful write operation	Active	Active
	Connected and a unsuccessful write operation	Active	Not Active
IO Unit	Not connected	Not Active	Not Active
	Connected	Active	Active
	Connected and successful read operation	Not Active	Active
	Connected and unsuccessful read.	Active	Not Active

4.7 IO Unit Configuration

4.7.1 Mode

The IO Unit can operate in two modes (see section 4.4 for the different HW configurations).:

1. Sending IO data to and from a host over the UART. Later called **UART mode**. (Basic 2). This is used for the Modular IO units.

2. Receiving IO data directly on the analogue and digital inputs of the module. Later called **direct IO mode**. (Basic 1) This is used for block IO units.

Each mode is configured using different firmware versions.

4.7.2 IO Type (Basic 2)

BT Unit handles IO type only (32-bits digital input and output + 2 analog in and 2 analog out).

When used in a gateway configuration the inputs are mirrored to the outputs and vice versa. This configuration handled by using two different FW versions (Gateway).

4.7.3 Tool Type (Robot)

For use on robots the tool type needs to be configured when the IO unit is mounted on a tool.

How to configure the Tool Type will be determined later in the project.

4.8 Bus Unit Configuration (Basic 1)

The Bus Unit always operates using the UART to communicate to the host. The configuration of the associated IO units may be read using diagnostics messages (see section 4.10).

4.9 Configuration Management (Basic 2)

In general the will one firmware file for each type of configuration. The following configuration is available:

Name	Description
Host Unit P-to-P	Host Unit FW used in a point-to-point configuration. Supports I2C Memory Plug as well as Auto Pairing.
Host Unit Multipoint	Host Unit used in a multipoint configuration. Supports I2C Memory Plug only.
IO unit Direct IO	IO unit used in direct IO mode. Used for Block IO units. Supports I2C Memory Plug as well as Auto Pairing.
IO unit UART mode.	IO unit used in a UART mode. Used for Module IO systems. Supports I2C Memory Plug as well as Auto Pairing.
IO unit GW Direct IO	IO unit using direct IO mode but is used as the Master of a GW pair. Always used in combination with one “IO Unit Direct IO” unit (Gateway). Supports I2C Memory Plug as well as Auto Pairing.

4.10 Additional PSKeys

4.10.1 Output Power Control

To support different antennas with higher gains there is a possibility to set the max output power of the unit (see section 4.2.4 for more info about the antennas used). This is done by modifying the following PSKey value:

PSKEY_LC_MAX_TX_POWER

The value is given in dBm steps. The recommended values are (corresponds to the values in the automatic power control table used by the module to automatically adjust the output power):

16, 12, 8 … 0 dBm (in 4dB steps).

Note! The value set is automatically adjusted to the closest smaller value in the power table. This means that the highest possible output value to use is 16 dBm.

Use the CSR Test API or the CSR tools to modify this value.

4.10.2 Bluetooth Name

The Bluetooth Name of the device may be changed by modifying the PSKey with the following name:

PSKEY_DEVICE_NAME

The name is stored in arrays of uint16s, the name is packed in this pskey, two octets per uint16.

Working from start of the device's name, the first character is stored in the lower octet of the pskey's first uint16, the second character in the upper octet of the first uint16, etc. If the name is an odd number of characters then the upper octet of the last uint16 is '\0'.

The Bluetooth name has maximum length of 8 characters (to support the diagnostics messages, see section 4.11).

4.11 Diagnostics and Management Protocol (Step 2)(Diagnostics)

This section describes the diagnostic and management protocol for the BT IO. The diagnostics and management data is acquired using a message-based protocol over UART. The protocol is described below.

The configuration/diagnostics protocol in a request and response manner. A Host request configuration/diagnostic data by sending a specific request. The Host waits until a response is received. The response holds the requested information.

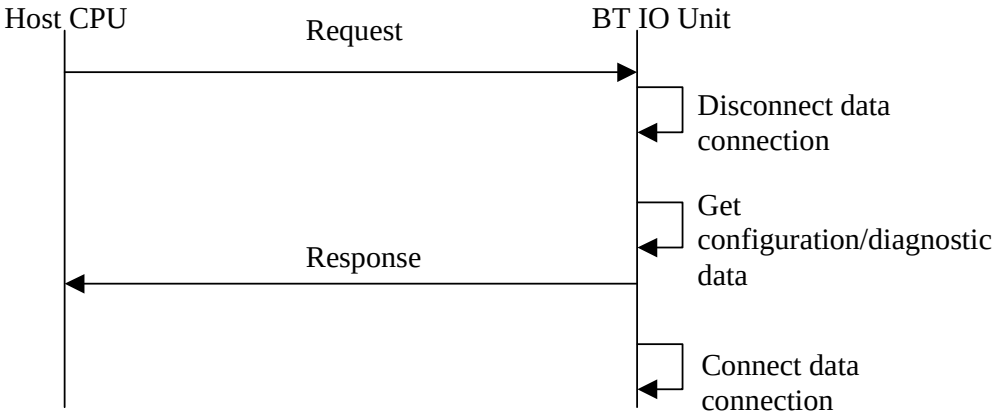


Figure 13 - Displays how messages are sent and received when acquiring configuration/diagnostics information from the BT IO. All messages are sent/received using the UART.

The message-based protocol works by filtering out all configuration/diagnostics messages from the UART. The filter decides whether it has received a data message or a configuration/diagnostics message. Data messages are directly routed to the corresponding IO unit. Configuration messages are routed to the application code on the Bus unit. The BT IO unit performs the following on reception of a configuration/diagnostics message.

1. The Bus unit disconnects the data connection on reception of a configuration message.
2. The BT IO creates a response package with the requested data. If a request requires information from a remote IO unit it will use the HID control channel, (GET_REPORT) with a certain report identifier, to acquire the requested information.
3. The BT IO returns the response.
4. The data pipe is reconnected when the configuration session is finished.

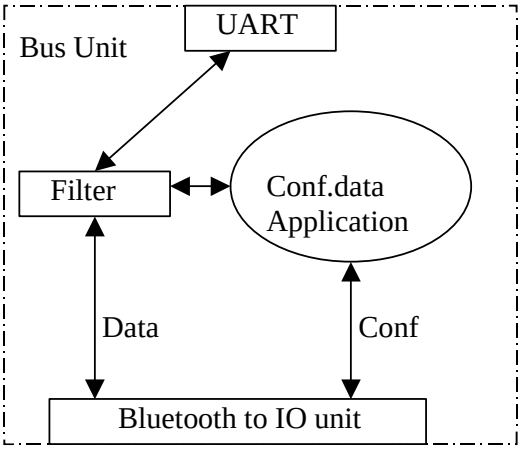


Figure 14 - Displays how configuration messages are routed in a Bus unit.

4.11.1 Management and Diagnostics messages

The protocol defines telegrams in format defined below. The telegrams start with a STX character and a channel identifier, which is used for multiplexing multiple IO units. The second part of the telegram is a basic HID packet, which contents depend on the purpose.

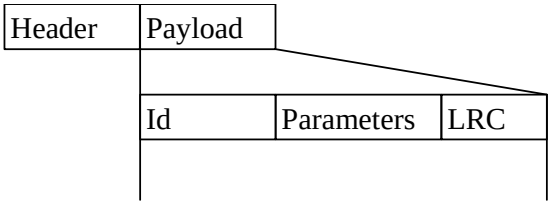
STX	Channel Id	HID control packet

The HID telegrams contents are described in HID specification version 1.0 [1]. A short description of the telegrams used is described below.

Note! Management and Diagnostics messages for the Robot option are not fully described in this document. Will be done when it are to be implemented.

4.11.1.1 Management and Diagnostics request package

This package is for sending diagnostics and configuration parameters to the BT IO. The header is always 0x43. Id identifies which paramter to return, the parameter field is a sub specification field to specify certain data pointed to by Id. The message is always 13 bytes long, none used fields should be set to 0x00. The last byte is a LRC of the complete message.



4.11.1.1.1 Bluetooth device address request

This request is for reading the Bluetooth address of a unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x81 specifies that a unit's Bluetooth address shall be read.	0x81	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.2 Bluetooth device name request

This request is for reading a unit's Bluetooth device name.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x82 specifies that a unit's Bluetooth device name shall be read.	0x82	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.3 IO unit operating mode request

This request is for reading the operating mode of a unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX character	0x02	0
Channel Id	Identifies the end point. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x83 specifies that the operating mode shall be read.	0x83	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.4 IO unit connection status request

This request is for reading the connection status of a unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x84 specifies that the connection status shall be read.	0x84	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.5 Set associated IO unit fail-safe mode request (Basic 2)

This request is for setting the fail-safe mode of an IO unit associated with the Bus unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x85 specifies that the fail-safe mode shall be set.	0x85	3
Failsafe mode	0x00 is running mode and 0x01 is fail-safe mode	0x00-0x01	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.6 Get associated IO unit fail-safe mode request

This request is for getting the fail-safe mode of an IO unit associated with the Bus unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x86 specifies that the fail-safe mode shall be read.	0x86	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.7 Get associated IO unit channel identity request (Basic 2)

This request is for getting the channel identity off an IO unit associated with the Bus unit. The Bus unit uses this message at first connection with a new IO unit internally. This message CANNOT be sent by a host system communicating with the Bus unit.

Header	Id	Byte2	Byte3	.....	Byte10	LRC

Name	**Description**	**Value**	**Byte**
Header	Is always 0x43 for configuration/diagnostics request.	0x43	0
Id	0x87 specifies that the IO units channel identity shall be read.	0x87	1
N.A	Not used should all be set to 0x00.	0x00	2-10
LRC	Calculated on bytes 0-11.	0xXX	11

4.11.1.1.8 Set number of associated IO units request (Basic 2)

This request is for setting the number of IO units that will try to connect to a Bus Unit. This is sent initially from the host to the Bus Unit and can only be sent once. When all of the IO units has connected the Bus Unit will leave connectable mode.

STX	Header	Id	NoIO	Byte4	.....	Byte12	LRC

Name	**Description**	**Value**	**Byte**
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x88 specifies that this message is used to set number of IO units.	0x88	3
NoIO	Number of IO Units that will try to connect.	0x01-0x07	4

N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.9 Link quality request

This request is for reading of the Bluetooth link quality.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x89 specifies that the link quality shall be read.	0x89	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.10 RSSI request

This request is for reading of the RSSI value.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x8A specifies that RSSI value shall be read.	0x8A	3

N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.11 Bluetooth passkey request

This request is for reading the Bluetooth passkey for a unit.

STX	Ch Id	Header	Id	Byte4	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2
Id	0x8B specifies that a unit's Bluetooth passkey shall be read.	0x8B	3
N.A	Not used should all be set to 0x00.	0x00	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.1.12 Set Bus Position request (I2C Management)

This request is for writing the Bus Position into the I2C plug currently connected to the Bus Unit.

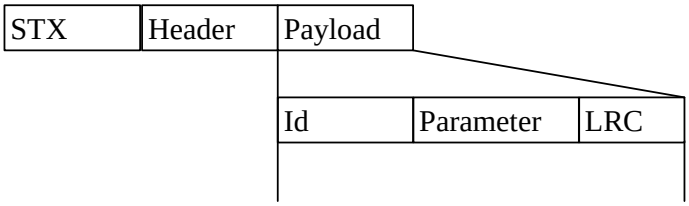
STX	Header	Id	Bus Position	Byte4	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0x43 for configuration/diagnostics request.	0x43	2

Id	0x8C specifies that this message is used to set number of IO units.	0x8C	3
Bus Position	Bus Position associated with the current I2C plug	0x01-0x07	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2 Management and Diagnostics response package

This package is returned in response to a diagnostics or configuration request . The header is always 0xA3. Id identifies which parameter that is returned. The parameter field holds the requested parameter. The size of a respones is fixed to 14 bytes. Bytes with no data should be set to 0x00. The last byte is a LRC off the complete message.



4.11.1.2.1 Bluetooth device address response

This message is returned in response to the Bluetooth device address request.

STX	Ch Id	Header	Id	BT_Addr 0	BT_Addr 1	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x81 specifies that a Bluetooth address shall be read.	0x81	3
BT_Addr0	MSB of the Bluetooth address.		4
BT_Addr1			5

BT_Addr2			6
BT_Addr3			7
BT_Addr4			8
BT_Addr5	LSB of the Bluetooth address.		9
N.A	Not used should all be set to 0x00.		10-12
LRC	Calculated on bytes 2-12.	0xXX	13

A Bluetooth address of 008037112233 is represented a follows in BT_Addr0 - BT_Addr5.

BT_Addr0	0x00
BT_Addr1	0x80
BT_Addr2	0x37
BT_Addr3	0x11
BT_Addr4	0x22
BT_Addr5	0x33

4.11.1.2.2 Bluetooth device name response

This message is returned in response to the Bluetooth device name request.

STX	Ch Id	Header	Id	Name0	Name1	.....	Name8	LRC

Name	**Description**	**Value**	**Byte**
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x82 specifies that a unit's Bluetooth device name have been read.	0x82	3

Name0-8	Local name string. Remaining bytes shall be set to 0x00 if name is shorter.	0xXX	4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.3 IO unit operating mode response

This message is returned in response to the operating mode of an IO unit request.

STX	Ch Id	Header	Id	Oper mode	Byte5	....	Byte12	LRC

Name	**Description**	**Value**	**Byte**
STX	STX Character	0x02	0
Channel Id	Specifies the source. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x83 specifies that the operating mode have been read.	0x83	3
Oper mode	0x01 is for UART mode and 0x02 is for IO mode.	0x01-0x02	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.4 IO unit connection status response

This message is returned in response to the connection status request.

STX	Ch Id	Header	Id	Con stat	Byte 5	.....	Byte12	LRC

Name	**Description**	**Value**	**Byte**
STX	STX Character	0x02	0
Channel Id	Specifies the source. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	1

Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x84 specifies that the connection status have been read.	0x84	3
Con stat	Specifies the connection status of an IO unit. 0x00 is disconnected and 0x01 is connected.	0x00-0x01	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.5 Set associated IO unit fail-safe mode response

This message is returned in response to the set the fail-safe mode of an IO unit request.

STX	Ch Id	Header	Id	Failsafe mode	Byte5	.....	Byte12	LRC

Name	**Description**	**Value**	**Byte**
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x01-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x85 identifies that an IO unit's fail-safe mode has been set.	0x85	3
Failsafe mode	Specifies if the command was properly executed. 0x00 = running mode and 0x01 = failsafe mode.	0x00-0x01	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.6 Get associated IO unit fail-safe mode response

This message is returned in response to the get the fail-safe mode request.

STX	Ch Id	Header	Id	Failsafe mode	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x01-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x86 identifies that a remote Bluetooth address shall be read.	0x86	3
Failsafe mode	Specifies the fail-safe mode status that has been read. 0x00 = running mode and 0x01 = failsafe mode.	0x00-0x01	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.7 Get IO unit channel identity response (Basic 2)

This message is returned in response to the get channel identity request. This is a response that is used internally by the Bus unit. This response shall never be sent from the Bus unit.

Header	Id	Ch Id	Byte 3	.....	Byte10	LRC

Name	Description	Value	Byte
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	0
Id	0x87 identifies that this is a response to reading of the channel identifier.	0x87	1
Ch Id	The channel identifier for this IO unit	0x01-0x07	2
N.A	Not used should all be set to 0x00.	0x00	3-10
LRC	Calculated on bytes 1-11.	0xXX	11

4.11.1.2.8 Set number of associated IO units response (Basic 2)

This message is returned in response to the set the number of IO units message.

STX	Ch Id	Header	Id	NoIO	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0xA3 for configuration/diagnostics response.	0xA3	2
Id	0x88 specifies that this is a response to a setting of maximum number of connecting IO units.	0x88	3
NoIO	Number of IO Units that will try to connect.	0x00-0x07	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.9 Link quality response

This message is returned in response to the link quality request.

STX	Ch Id	Header	Id	Quality	Byte4	.....	Byte11	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x89 specifies that the link quality has been read.	0x89	3
Quality	Byte containing the link quality value (see section Link quality indicationfor description of the meaning of the value).	0xXX	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.10 RSSI response

This message is returned in response to the link quality request.

STX	Ch Id	Header	Id	RSSI value	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x8A specifies that the RSSI value have been read.	0x8A	3
Quality	A signed 8-bit integer containing the RSSI value. See reference 3 for more details about this value.	0xXX	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.11 Bluetooth passkey response

This message is returned in response to the Bluetooth passkey request.

STX	Ch Id	Header	Id	Passkey0	Passkey1	.....	Passkey8	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x00-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data response.	0xA3	2
Id	0x8B specifies that a unit's Bluetooth passkey have been read.	0x8B	3
Passkey 1-8	Passkey string. Remaining bytes shall be set to 0x00 if name is shorter.	0xXX	4-12

LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.2.12 Set Bus Position response (I2C Management)

This message is returned in response to the Set Bus Position message.

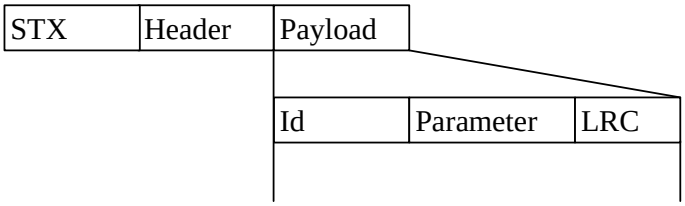
STX	Ch Id	Header	Id	Result	Byte5	.....	Byte12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit.	0x00	1
Header	Is always 0xA3 for configuration/diagnostics response.	0xA3	2
Id	0x8C specifies that this is a response to a setting of maximum number of connecting IO units.	0x8C	3
Result	Result. 0x00 = Successful write operation, 0x01=Plug bot available, 0x02 = Other write error.	0x00-0x02	4
N.A	Not used should all be set to 0x00.	0x00	5-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.3 Management and Diagnostics Indication Package

This section describes the management and Diagnostics indication packages. They are built up in the same way as the response/request packages. The only difference is that they are sent upon certain events described below.

The header is always 0xA3. Id identifies which paramter that is returned. The parameter field holds the indication parameter. The size of a indication is fixed to 13 bytes. Bytes with no data should be set to 0x00. The last byte is a LRC off the complete message.



4.11.1.3.1 Fail safe mode indication (Basic 2)

This message is sent from the Bus unit to the Host upon a detection of that the IO unit has entered fail-safe mode.

STX	Ch Id	Header	Id	Byte 4	….	Byte 12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	1
Header	Is always 0xA3 for configuration/diagnostics data indication.	0xA3	2
Id	0x8D specifies that failsafe mode enter indication.	0x8D	3
N.A	Not used should all be set to 0x00.		4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.1.3.2 I2C Plug Present Indication (I2C Management)

This message is sent from the Bus unit to the Host upon a detection of an I2C plug on the base unit.

STX	Ch Id	Header	Id	Byte 4	….	Byte 12	LRC

Name	Description	Value	Byte
STX	STX Character	0x02	0
Channel Id	Identifies the source. The value of 0x00 identifies the Bus unit (can only be received from the Bus Unit).	0x00	1
Header	Is always 0xA3 for configuration/diagnostics data indication.	0xA3	2
Id	0x8E specifies that I2C Plug Present indication.	0x8E	3
N.A	Not used should all be set to 0x00.		4-12
LRC	Calculated on bytes 2-12.	0xXX	13

4.11.2 LRC

The LRC field is one byte, containing an 8-bit binary value. The LRC value is calculated by the transmitting device, which appends the LRC to the message. The receiving device calculates an LRC during receipt of the message, and compares the calculated value to the actual value it received in the LRC field. If the two values are not equal, an error results.

The LRC is calculated by adding together successive 8-bit bytes of the message, discarding any carries, and then two's complementing the result. The LRC is calculated on the complete message excluding the channel identifier.

4.12 Data Communication between the host and the Bus unit (Basic 2)

This data communication is used for setting/receiving data to/from the Bus units associated IO units. The protocol is defined in the following sections.

4.12.1 Data messages

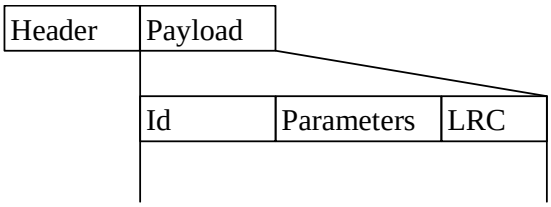
The telegrams start with a channel identifier, which is used for multiplexing multiple IO units. The second part of the telegram is a basic HID data packet, which contents depend on the purpose.

Channel Id	HID data packet

The HID telegrams contents are described in HID specification version 1.0 [1]. A short description of the telegrams used is described below.

4.12.1.1 Data set package

This package is for writing AIO and PIO values to a BTIO unit. The header is always 0xA1. Id identifies the contents of the data package.The parameter field is contains the data described by Id. The message is always odd bytes long, none used fields should be set to 0x00. The last byte is a LRC of the complete message. This request is send by the host to the bus unit when a set action is requiered.



4.12.1.1.1 Data set package direct IO mode

This request is for setting the PIO and AIO values.

Ch Id	Header	Id	Byte3	Byte4	.....	Byte11	LRC

Name	**Description**	**Value**	**Byte**
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	0
Header	Is always 0xA2 for data packages.	0xA2	1
Id	0x05 specifies the data parameters as described below.	0x05	2
PIO 8-15		0xXX	3
PIO 0-7		0xXX	4
PIO 24-31		0xXX	5
PIO 16-23		0xXX	6
AIO 1 MSB	AIO 1 most significant byte of the AIO word.	0xXX	7
AIO 1 LSB	AIO 1 least significant byte of the AIO word.	0xXX	8
AIO 2 MSB	AIO 2 most significant byte of the AIO word.	0xXX	9
AIO 2 LSB	AIO 2 least significant byte of the AIO word.	0xXX	10
N.A	Not used should all be set to 0x00.	0x00	11
LRC	Calculated on bytes 1-11.	0xXX	12

4.12.1.1.2 Data set package UART mode

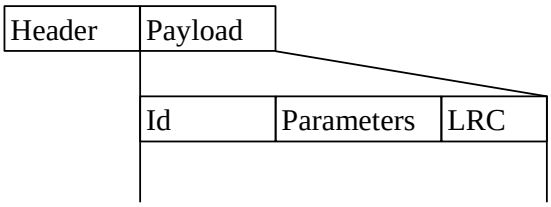
This request is for sending data to an IO Unit in UART mode.

Ch Id	Header	Id	Byte3	Byte4	.....	Byte11	LRC

Name	**Description**	**Value**	**Byte**
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	0
Header	Is always 0xA2 for data packages.	0xA2	1
Id	0x06 specifies the data parameters as described below.	0x06	2
Data		0xXX	3-11
LRC	Calculated on bytes 1-11.	0xXX	12

4.12.1.2 Data change package

This package is received when AIO and PIO values changes in a BTIO unit. The header is always 0xA1. Id identifies the contents of the data package.The parameter field contains the data described by Id. The message is always odd bytes long, none used fields should be set to 0x00. The last byte is a LRC of the complete message. This response is produced by the BTIO unit whenever a PIO and/or AIO change is deteceted.



4.12.1.2.1 Data change package for direct IO mode

This response describes the PIO and AIO values.

Ch Id	Header	Id	Byte3	Byte4	.....	Byte11	LRC

Name	**Description**	**Value**	**Byte**
Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	0
Header	Is always 0xA1 for data packages.	0xA1	1
Id	0x05 specifies the data parameters as described below.	0x05	2
PIO 8-15		0xXX	3
PIO 0-7		0xXX	4
PIO 24-31		0xXX	5
PIO 16-23		0xXX	6
AIO 1 MSB	AIO 1 most significant byte of the AIO word.	0xXX	7
AIO 2 LSB	AIO 2 least significant byte of the AIO word.	0xXX	8
AIO 2 MSB	AIO 2 most significant byte of the AIO word.	0xXX	9
AIO 2 LSB	AIO 2 least significant byte of the AIO word.	0xXX	10
N.A	Not used should all be set to 0x00.	0x00	11
LRC	Calculated on bytes 1-11.	0xXX	12

4.12.1.2.2 Data change package for UART mode

This response describes the PIO and AIO values.

Ch Id	Header	Id	Byte3	Byte4	.....	Byte11	LRC

Name	**Description**	**Value**	**Byte**

Channel Id	Identifies the end point. The value of 0x00 identifies the Bus unit. The value of 0x01-0x07 identifies an IO unit.	0x01-0x07	0
Header	Is always 0xA1 for data packages.	0xA1	1
Id	0x06 specifies the data parameters as described below.	0x06	2
Data		0xXX	3-11
LRC	Calculated on bytes 1-11.	0xXX	12

4.13 Data flow between the Bus Unit host and the BT Host CPU

The Bus Unit Host CPU (called IBS later) communicates with BT Host CPU over a UART interface. The messages are passed using a synchronous method (see Figure 15 below).

The figure shows an example with two IO units. Some comments to the figure (see markers in the figure):

1. You send data to each of the x units one by one (how many depends on how many slaves you have, in the example it is two). When a correct message is received two (no of bytes, checksum etc. is checked) three situations may occur:

    a. If the received message is data message the message will be forwarded to the Bluetooth stack for transfer to the remote unit and latest received data message from the remote unit will be passed back to the IBS.

    b. As a response to a data message an indication message may be sent e.g. when an IO unit enters fail-safe mode (see section 4.11.1.3.1).

    c. If the received message is a diagnostics request package the BT Host unit will directly start to threat this and reply with the corresponding response message.

   If an incorrect message is received the BT unit will not respond. Timeout supervision is required in the IBS (the timeout time needs to be decided later). When the timeout time has passed the sequence is continued (it means that data will be sent the next time the BT Host unit is "polled").

2. Data set message is sent when the next sniff slot for addressed slave occurs. If more than one message is received from IBS between two slots the oldest ones are disposed and latest is used.

3. Date change messages arrive at the BT Host independent of when the IBS "polls" it. The BT Host stores that latest received value and this is sent at the next time an IBS poll for this slave arrives.

BT IO Functional Description

NOTE! At power up the Bus Unit will wait for an initial “Set number of associated IO units request” message (see section 4.11.1.1.8). Before this message is received and responded to, the Host unit will not respond to any messages from the IBS.

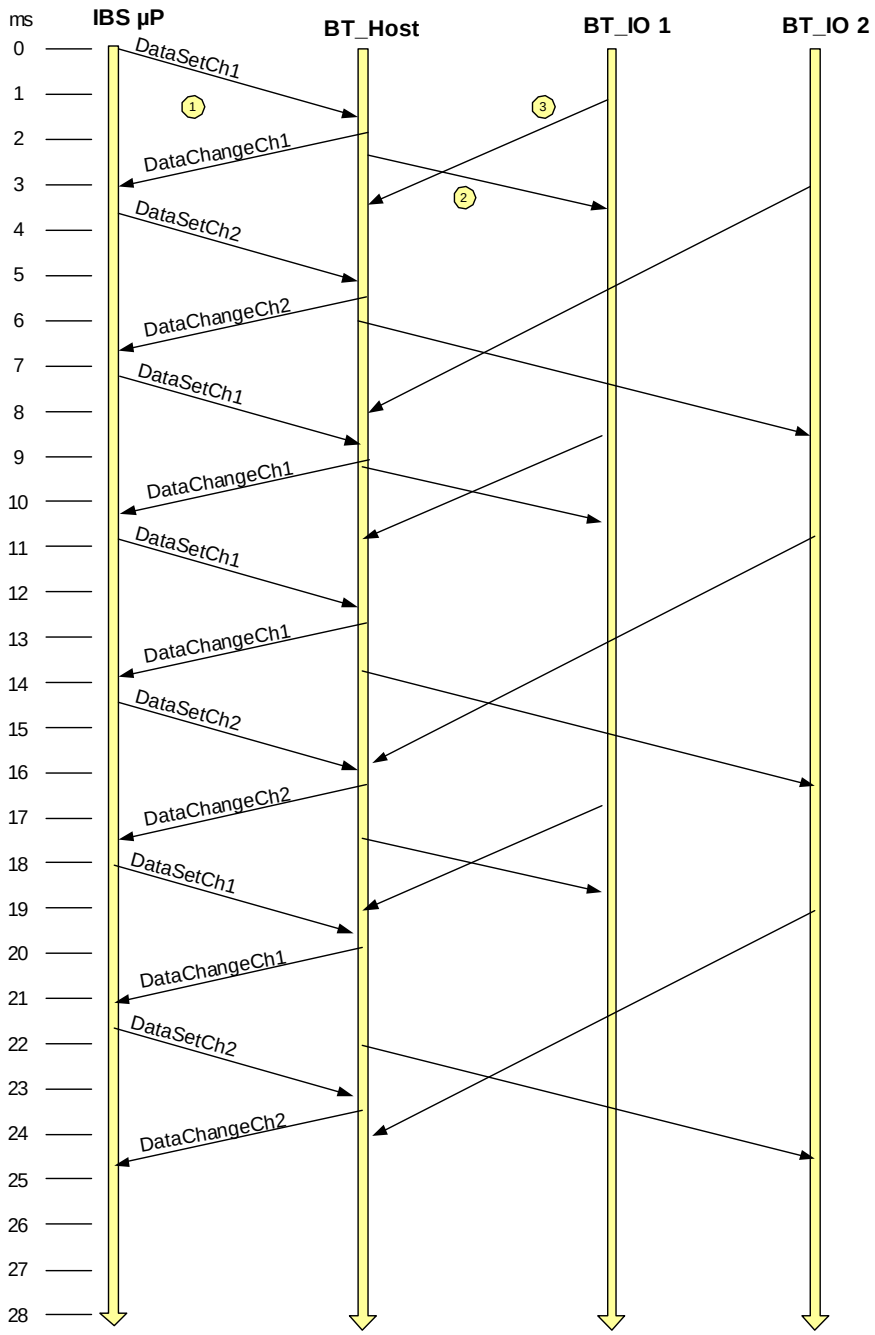


Figure 15 - Synchronous Message Passing (time axis just for reference, not real values)

4.14 Connection Establishment (Basic 2)

The establishment of a Bluetooth connection between two devices is made at the set up phase of a new system or at service. Once two devices have established a connection, these devices are paired and will always connect to each other automatically.

4.14.1 Bus Unit initialisation (Basic 2)

The Bus Unit needs information about the number of IO Units that will connect. This is done by configuration message “Set number of associated IO units request” (ID 0x8A). This message is sent once after power up of the Bus Unit.

The Bus Unit will accept this number of IO units only. After the last unit is connected it will leave its “connectable” mode. If an IO unit disconnects it will be set to “connectable” again.

The reasons for this are to optimise the use of the radio link. A “connectable” unit will reserve a certain part of the radio bandwidth for listening for a connection.

4.14.2 Configuration of connection information - I2C Memory Plug

The IO Unit is configured to connect directly to the Bus Unit using the Bus Unit Bluetooth device address and passkey. The address and passkey is transferred to the IO unit using a removable I2C memory that the IO unit can access during start up. This memory contains the following information:

- The Bus Unit’s Bluetooth device address.
- The Bus Unit’s passkey.

The I2C Bus Member Address is used to identify the channel ID when used in a multipoint configuration (see section 4.5).

The information is written into the I2C memory when placed on the Bus Unit. The IO Unit has the same interface, which it uses to read the information at power up.

4.14.3 Connection Scheme

The BT unit connects to another BT unit using the connection scheme described below. The initiator of the connection is the IO Unit and the connected is the Bus Unit.

The scheme is based around two start-up conditions, power up and wake up. Power up is when the unit is powered up for the first time after a shut down. Wake up is when the unit goes from a sniff mode with a long sniff period (100ms) to a short sniff period (5ms), from idle to being active communicating data. Wake up mode can only be realised if the IO Unit is continuously powered when idle, with batteries or a super cap.

Power up (Basic 2):

1. IO Unit: Reads the Bluetooth device address of the Bus unit using I2C memory device connected to the IO.

2. IO Unit: If the IO unit is paired with the Bus unit it connects directly to the Bus Unit, otherwise bonding is performed prior to connect.

Wake up (Robot):

1. IO Unit: The IO unit is woken from sniff mode and directly starts send IO data.

The IO unit reads the Bus Unit BD address and passkey and from an I2C memory placed on the IO unit, see the configuration chapter. The channel identity is also read from the I2C memory; the identity is later used by the Bus unit to multiplex IO units. The Bus unit reads this identity number from the IO unit at start-up. The Bus unit uses the HID Control channel to read the identity from the IO unit, see chapter 4.8.1.1.9 and 4.8.1.2.9 for specification off the used messages.

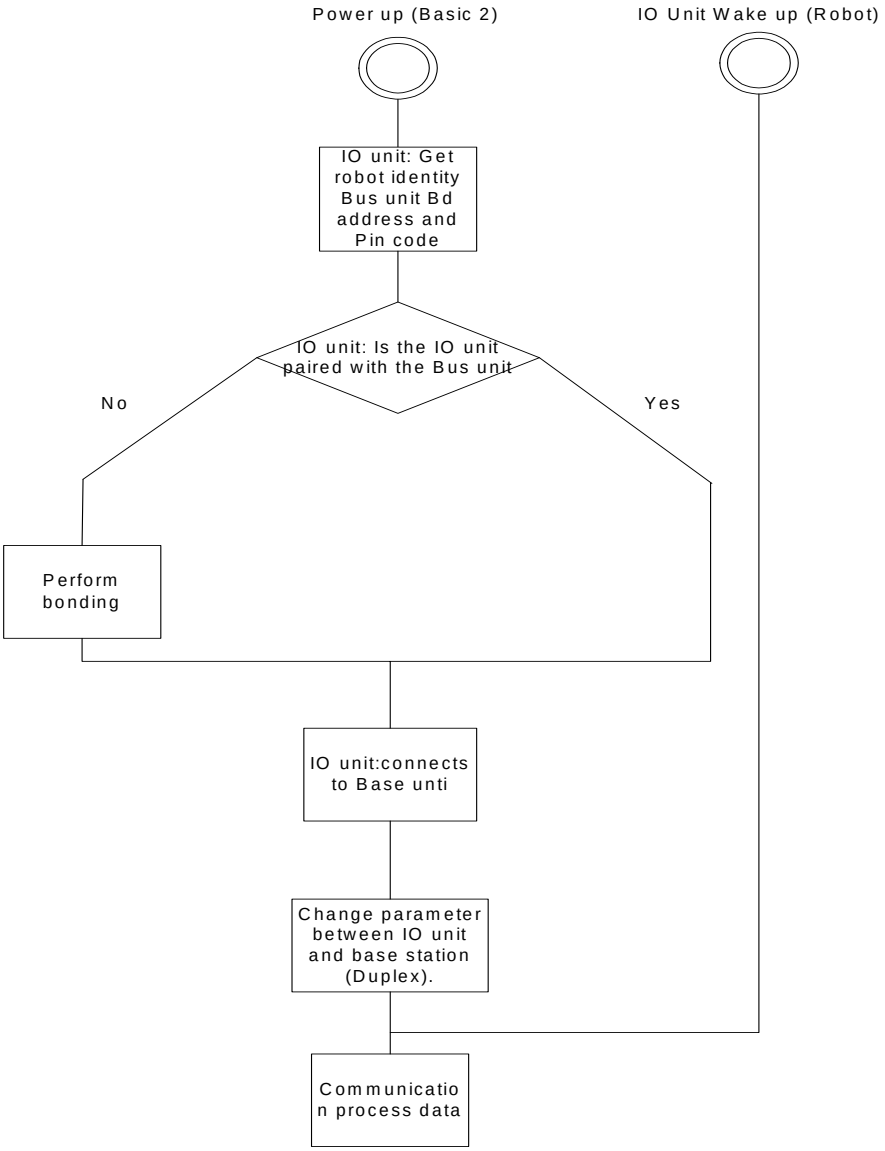


Figure 16 - Displays the connection scheme for the BT unit.

4.14.4 Connection Time

The BT IO specifies two different connection scenarios with different connection times:

- Fast connection that occurs when the IO Unit is in wake up mode but not disconnected. (Robot)
- Slow connection that occurs when the IO Unit is in power up mode. (Basic 2)

The fast connection mode is realized using sniff mode with a long sniff period (100ms). This means that the IO Unit is synchronized to the Bus Unit, which enables fast activation into running mode and communicating data. (Robot)

Connection mode	Connection time [ms][1]
Fast connection	100
Slow connection	3000

4.14.5 Disconnection (Robot)

The IO Unit will repeatedly be disconnected from the Bus Unit, i.e. when changing tools on the robot or when maintenance is performed. The IO Unit has no external power source during this time, which will force the power up mode when reconnecting. It is more optimal if the unit goes to wake up mode on disconnection, which enables fast communication establishment when the IO Unit is reconnected.

The IO Unit can operate in wake up mode (sniff mode with long sniff period), still being synchronized to the Bus Unit, when the IO is disconnected. Wake up mode uses a longer sniff period; a long sniff period (100ms) consumes less power than a short sniff period (5ms), than when the communication is running. Wake up mode allows the IO Unit to quickly be reactivated in the Bus Unit's piconet due to that it is synchronized with the Bus Unit, however it demands some kind of power source. This can is realized with batteries or a super cap mounted on the IO Unit.

The IO Unit will restart from power up mode when no super cap or battery power source is present.

4.15 Security (Basic 2)

The Bluetooth communication link is protected by Bluetooth's security mechanisms, encryption and authentication. Neither the IO Unit nor the Bus Unit is discoverable when using the connection scheme described above, which adds more security to the communication link. Unauthorized Bluetooth units cannot find undiscoverable units, which block these units from affecting the transmitted information.

4.16 Fail-safe mode (Basic 2)

4.16.1 Fail-safe detection

Fail-safe mode is entered whenever a fail is detected in the Bluetooth communication. A fail can occur due to power failure, radio disruption or radio interference.

Fails are detected using the following Bluetooth supervision mechanisms:

- A standard Flush Timeout, which alerts if data has not been transmitted within the timeout period.

[1] Preliminary. Needs to be verified.

- A watchdog timer on received data packets, which alerts if data has not been received within the timeout period. The watchdog timer is reset on reception on consistent data.

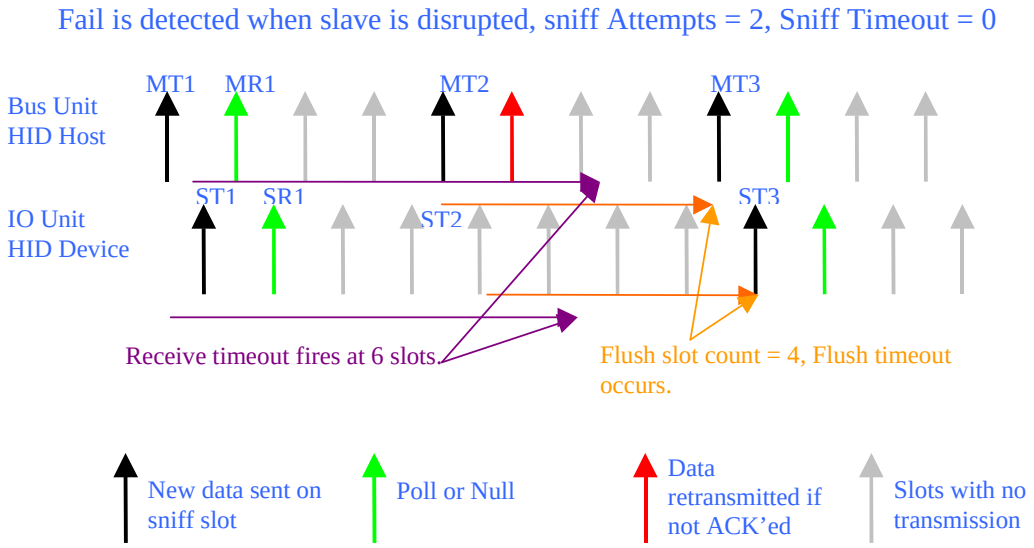


Figure 17 - Display show a fail is detected using both the flush timeout and watchdog timer supervision mechanisms. The IO unit has in the case fallen through and is not accessible.

A fail is detected and notified within the following times:

Fail source	Notification time[2]	Units
Bus unit	20	ms
IO unit	20	ms

The fail notification times indicated in the tables assumes a point-to-point connection with a sniff interval of 5 ms. This is not applicable in a multi-point scenario. The notification times in a multi-point scenario needs to be investigated in more detail.

4.16.2 IO-unit fail-safe management (Basic 2)

If an IO Unit running in direct IO mode detects a communication failure (as described in section 4.16.1) it will automatically set the associated IO to fail-safe values i.e.:

- Digital outputs will be set to 0
- Analog outputs are set to the 0.0.

[2] Preliminary figures. Needs to be verified during the detailed design. To be verified what is possible if the unit is used in a multi-point configuration.

If the IO unit operates in UART mode, it will notify fail-safe mode to the host using the diagnostics interface (see section 4.10). When the communication is re-established, the IO Unit will **NOT** automatically revert back to running mode. In this case is the host CPU on Bus unit is responsible for telling the IO Unit move back from fail-safe mode to running mode (see diagnostics message 4.11.1.1.5).

The IO unit may enter fail-safe mode on command from its Bus Unit using the management/diagnostics interface (Step 2). In this case another management/diagnostics command is used to set the unit back to normal operation. More on the management/diagnostics messages from the Bus Unit to the IO Unit is given in section In this case is the same management functions as indicated above are performed (what is depending on if the unit is operating in UART or in direct IO mode).

4.16.3 Bus Unit fail-safe management (Basic 2)

If a Bus Unit detects a communication failure (as described in section 4.16.1) it will notify the host CPU of this using the diagnostics interface (see section 4.10). When the communication is re-established this will be notified to the host (using the diagnostics interface, see section 4.10).

4.17 “Polling” scheme and latency

The implementation of the “copying” of IO data over the air is implemented using the Bluetooth HID profile. The HID profile is using Bluetooth Sniff mode to implement the polling scheme. The IO Unit and the Bus Unit is synchronized in time and every x ms interval (called sniff interval) they wakes up and are ready to interchange data. The sniff interval will decide the latency.

An IO change is measured from the IO interface on the IO Unit to the field bus interface on the Bus Unit, see Figure 18.

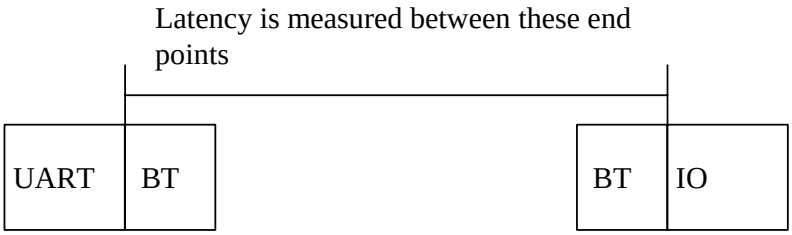


Figure 18 - Displays the end points for measuring the IO latency.

4.18 Point-to-point scenario and latency

4.18.1 Basic point-to-point (Basic 2)

The aim is an intermediate latency of 7 ms that jitters up to a maximum of 10 ms.

4.18.2 Advanced point-to-point (Step 2)

The aim is to achieve a maximum latency of 5 ms (maximum jitter is 5 ms).

4.19 Multi-point scenario and latency

The implementation of the IO is based on the Bluetooth HID profile. The Bluetooth HID profile supports a multi-point scenario where multiple IO units might be connected to one Bus Unit (a maximum of 7 is allowed).

The basic functionality is the same in a multi-point scenario as in the point-to-point scenario but depending on the number of active slaves the HID sniff interval must be extended. This will influence the latency for the individual slaves. The algorithm for setting up the sniff interval needs to be decided in the project.

4.19.1 Basic multi-point (Basic 1)

This scenario support basic multi-point but is not optimized for latency. The following latencies are aimed for:

No of slaves	Latency[3]
3	15-20 ms
7	25-35 ms

4.19.2 Advanced multi-point (Step 2)

This scenario support advanced multi-point optimized for latency. The following latencies are aimed for:

No of slaves	Latency[4]
3	< 10ms
7	< 15 ms

4.20 Range (Basic 2)

Class	Max Range	Hardware Type
20 dBm	100 – 200 m	connectBlue BT unit with external PA and LNA

4.21 Power consumption (Basic 2)

The BT unit operates in several different modes each with specific power consumption. These values are preliminary at current stage.

[3] Preliminary figures. Needs to be verified during detailed design.
[4] Preliminary figures. Needs to be verified during detailed design.

BT IO Functional Description

Power mode	Average[5]	Units
Run mode communication full speed	45	mA
Run mode idle [IO unit = slave]	22	mA
Run mode idle [Bus unit = master]	5	mA
Wake up mode sniff period 100ms [IO unit]	1	mA
Power up mode disconnected [IO unit]	0	mA

[5] These figures are preliminary and needs to be verified in the design phase.

5 Qualification and Test (Basic 2)

The BT Unit shall be Bluetooth qualified for the HID profile. The Bluetooth hardware is pre qualified by CSR but some additional Bluetooth tests are required (some basic radio tests). The BT Unit is qualified as an end product, which means that the BT unit (IO Unit and Bus Unit) can be mounted in several products without any further Bluetooth qualification.

6 Regulatory Information

6.1 FCC Compliance

6.1.1 FCC Statement

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.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help

6.1.2 RF-exposure Statement

This modular transmitter MUST have a separation distance of at least 20cm between the antenna and the body of the user or nearby persons.

Any notification to the end user of installation or removal instructions about the integrated radio module is NOT allowed.

6.1.3 Antenna

Our module type cB-0719-02 is for OEM integrations only. The end-user product will be installed in such a manner that only the authorized antennas are used.

6.1.4 Caution

Any changes or modifications NOT explicitly APPROVED by connectBlue AB could cause the module to cease to comply with FCC rules part 15, and thus void the user’s authority to operate the equipment.

6.2 IC Compliance

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.

This device has been designed to operate with an antenna having a maximum gain of 9 dB. Antenna having a higher gain is strictly prohibited per regulations of Industry Canada. The required antenna impedance is 50 ohms

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that required for successful communication.

6.3 Safety

The unit must be supplied by a limited power source in according to EN 60950-1.

6.4 Label and manual requirements for the End Product

For an end product using the BT Unit there must be a label containing, at least, the following information:

This device contains FCC ID: PVH071902 IC: 5325A-0719X

The label must be affixed on an exterior surface of the end product such that it will be visible upon inspection in compliance with the modular approval guidelines developed by the FCC.

Where the module will be installed in final products larger than 8 cm x 10 cm following statement has to be placed ONTO the device.

“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.”

In case, where the final product will be installed in locations where the end-consumer is not able to see the FCC ID and/or this statement, the FCC ID and the statement shall also be included in the end-product manual.