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CISS - Connected Industrial Sensor Solution

USB Communication Protocol – Version 2.0

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1 General Information

CISS is a multi-sensor IoT device with eight sensors. It is developed for industrial retrofit applications such as condition monitoring and predictive maintenance.

CISS can communicate over Universal Serial Bus (USB 2.0) or Bluetooth Low Energy (BLE).This document is the USB Communication Protocol which explains the details about the USB interface of the device. It presents how to setup the device, get data over USB and the format of the data frames.

This document refers to CISS firmware version v02.03.00.

Please ensure that the CISS is working correctly by reading the operating instructions document (available to download) carefully before using the device in your application.

In the host device, Windows/Linux (e.g. gateway), that you connect to the CISS, you may use generic drivers to have a Virtual Com Port for the interaction with your application.

Please note that there is a **Python script available** to download in the webpage. The Python script includes some example implementations of the USB interface. It can speed up your integration. Please download and have look.

1.1 Definition of special notices

Note: Indicates important notes, information, tips about the communication of the device. Please pay attention to this points.
➔ **Always follow these instructions**

2 CISS USB Communication Protocol

2.1 USB Frame Format

The USB frame of the CISS has a standard format, which is shown in the following table. The frame can be a command, acknowledgement or a data frame. The data is always in **hexadecimal LSB first format**. The frame starts with a Start of Byte (SOF), which is always "0xFE", then the length of the type/ID + payload and at the end 1 byte for cyclic redundancy check (CRC) code. Calculation of the CRC checksum is explained below.

SOF (1 byte)	Length (1 byte)	Type/ID (1 byte)	Payload (0-255 bytes)	CRC (1 byte)
0xFE (always the same)	Length of payload (without CRC length)	Type of the frame (see all types below in the table)	Data Bytes	CRC Checksum

As an example the frame "0xFE 02 80 01 83" is a command to start acceleration data streaming. After stating byte ("FE") there is a length ("02") which tells that the type/ID + payload is 2 bytes, then 2 bytes of type/ID + payload data ("80 01") and finally 1 last byte for CRC.

If the data frame is a command, there will be the command data in the payload. After sending a command frame, CISS answers the frame with an Acknowledge (ACK) or Not-Acknowledge

(NACK) message. This is explained with details in related section below. All available CISS commands are explained in chapter 3 Commands and Settings.

Note: Please consider that all the data in the CISS data frames are formatted as **Least Significant Byte (LSB) first format**.

Note: Whenever a CISS sensor gets reconfiguration, the sampling will be stopped until the configuration is done. After the configuration, the sensor will automatically restart to send data with the new setting.

2.1.1 Frame Type/IDs

All the CISS frames has a type/ID after the length byte. This 1 byte of data is to identify the frame. In following table you may see all possible type/IDs.

Type/ID	Name / Description
0x01	Acknowledgement Message (ACK)
0xFF	Not-Acknowledgement Message (NACK)
0x02	Accelerometer Data Frame
0x03	Magnetometer Data Frame
0x04	Gyroscope Data Frame
0x05	Temperature data in Environmental Data Frame
0x06	Pressure data in Environmental Data Frame
0x07	Humidity data in Environmental Data Frame
0x08	Light Data Frame
0x09	Noise Data Frame (*Not available via USB*)
0x80	Accelerometer Command (sensor ID)
0x81	Magnetometer Command (sensor ID)
0x82	Gyroscope Command (sensor ID)
0x83	Environmental Sensor Command (sensor ID)
0x84	Light Sensor Command (sensor ID)
0x90	BLE Command
0x91	Timestamp Setting Command
0xFD	Time Aggregation Mode Command
0x7E	Time aggregation data frame for accelerometer and gyroscope
0x7D	Time aggregation data frame for temperature data
0xFC	Event Detection Mode Command
0x7A	Event Detection Mode data frame

2.1.2 Cyclic Redundancy Check (CRC) Code

The CRC of the frame is calculated by executing an XOR (exclusive OR gate) between the length byte and all bytes of the payload.

CRC = Length ^ Payload [0] ^ Payload [1] ^ … ^ Payload [n-1] ^ Payload [n]

As an example, in following table the CRC is calculated step by step.

SOF (1 byte)	Length (1 byte)	Payload (0-255 bytes)			CRC (1 byte)
0xFE	**0x03**	**0x5B**	**0x04**	**0x12**	**0x4E**

0x03 ^ **0x5B** = **0x58**

0x58 ^ **0x04** = **0x5C**

0x5C ^ **0x12** = **0x4E** → **CRC = 0x4E**

3 Commands and Settings

CISS has totally eight inclusive sensors. In this section, you can see how to setup the sensor parameters with special commands. How to start/stop data streaming with the commands etc.

Each sensor in the CISS has a unique ID. This Id is used in the command frames as frame type/ID. All command type/IDs are listed in the table in section 2.1.1 Frame Type/IDs.

1.1 Accelerometer Sensor Commands

In following table the structure of the accelerometer commands are specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x80 	0x00	-	Stop streaming accelerometer data. This will disable the accelerometer sensor. Disables the sensor by putting it to suspend mode.	**Example:** The complete command will be like “0xFE 02 **80 00** 82” After this command the CISS stops streaming accelerometer data
	0x01	-	Start streaming accelerometer data. This will enable the accelerometer sensor.	**Example:** The complete command will be like “0xFE 02 **80 01** 83” After this command CISS starts streaming

				accelerometer data. The data frame format is explained in 5.1.2 Accelerometer Data Frame.
	0x02	4 Bytes - Sampling Rate	Set the sampling rate for the inertial sensors. This sampling rate is common for all inertial sensors (accelerometer, gyroscope and magnetometer) Sampling rate must be between min: 10 milliseconds and max: 10 minutes The special Accelerometer_2kHz_Mode has a sampling rate of 500µs. This mode is explained in section 6.1 Accelerometer 2kHz Streaming Mode.	The new sampling rate must be provided in micro seconds (µs). The data part must be in LSB first order format. **Example**: You want to set 100ms sampling rate. 100ms=100000µs, 100000 = 0x000186A0 in Hex (4 bytes) and with LSB first format → 0x**A0860100**. So the complete command will be like "0xFE 06 **80 02 A0 86 01 00** A3"
	0x03	2 Bytes - Threshold	Set the threshold value in mg for the accelerometer. The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of current accelerometer measurement range (±2, 4, 8 or 16g) This threshold is used for all 3-axis (x, y, z) of the accelerometer.	**Example**: You want to set 50mg as threshold. 50 = 0x0032 in Hex (2 bytes) and with LSB first format 0x**3200**. So the complete command will be like "0xFE 04 **80 03 32 00** B5"
	0x04	1 Byte - Range	Set the measurement range of the accelerometer to ±2g, ±4g, ±8g or ±16g (Default is ±16g)	There are four allowed setting (±2g, ±4g, ±8g or ±16g) for the measurement range of the accelerometer. Complete commands are given below in the example. Example: ±2g → "0xFE 03 80 04 **02** 85" ±4g → "0xFE 03 80 04 **04** 83" ±8g → "0xFE 03 80 04 **08** 8F" ±16g → "0xFE 03 80 04 **10** 97"

3.1 Magnetometer Sensor Commands

In following table the structure of the magnetometer commands are specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x81 	0x00	-	Stop streaming magnetometer data. This will disable the magnetometer sensor. Disables the sensor by putting it to suspend mode.	**Example:** The complete command will be like “0xFE 02 **81 00** 83” After this command the CISS stops streaming magnetometer data
	0x01	-	Start streaming magnetometer data. This will enable the magnetometer sensor.	**Example:** The complete command will be like “0xFE 02 **81 01** 82” After this command CISS starts streaming magnetometer data. The data frame format is explained in 5.1.3 Magnetometer Data Frame.
	0x02	4 Bytes - Sampling Rate	Set the sampling rate for the inertial sensors. This sampling rate is common for all inertial sensors (accelerometer, gyroscope and magnetometer) Sampling rate must be between min: 10 milliseconds and max: 10 minutes The special Accelerometer_2kHz_Mode has a sampling rate of 500µs. This mode is explained in section 6.1 Accelerometer 2kHz Streaming Mode.	The new sampling rate must be provided in micro seconds (µs). The data part must be in LSB first order format. **Example**: You want to set 100ms sampling rate. 100ms=100000µs, 100000 = 0x000186A0 in Hex (4 bytes) and with LSB first format → 0xA0860100. So the complete command will be like “0xFE 06 **81 02 A0 86 01 00** A2”
	0x03	2 Bytes - Threshold	Set the threshold value in micro Tesla (µT) for the magnetometer. The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of magnetometer measurement range which is	**Example**: You want to set 50µT as threshold. 50 = 0x0032 in Hex (2 bytes) and with LSB first format 0x**3200**. So the complete command will be like “0xFE 04 **81 03 32 00** B4”

			±1300µT (x and y-axis); ±2500µT (z-axis). So a value between 0 and 2500µT makes sense. This threshold is used for all 3-axis (x, y, z) of the magnetometer.	

3.2 Gyroscope Sensor Commands

In following table the structure of the gyroscope commands are specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x82 	0x00	-	Stop streaming gyroscope data. This will disable the gyroscope sensor. Disables the sensor by putting it to suspend mode.	**Example:** The complete command will be like "0xFE 02 **82 00** 80" After this command the CISS stops streaming gyroscope data
	0x01	-	Start streaming gyroscope data. This will enable the gyroscope sensor.	**Example:** The complete command will be like "0xFE 02 **82 01** 81" After this command CISS starts streaming gyroscope data. The data frame format is explained in 5.1.4 Gyroscope Data Frame.
	0x02	4 Bytes - Sampling Rate	Set the sampling rate for the inertial sensors. This sampling rate is common for all inertial sensors (accelerometer, gyroscope and magnetometer) Sampling rate must be between min: 10 milliseconds and max: 10 minutes The special Accelerometer_2kHz_Mode has a sampling rate of 500µs. This mode is explained in section 6.1 Accelerometer 2kHz Streaming Mode.	The new sampling rate must be provided in micro seconds (µs). The data part must be in LSB first order format. **Example**: You want to set 100ms sampling rate. 100ms=100000µs, 100000 = 0x000186A0 in Hex (4 bytes) and with LSB first format → 0x**A0860100**. So the complete command will be like "0xFE 06 **82 02 A0 86 01 00** A1"

	0x03	2 Bytes - Threshold	Set the threshold value in Degree/Second (°/s) for the gyroscope. The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of gyroscope measurement range which is ±2000°/s. So a value between 0 and 2000 makes sense. This threshold is used for all 3-axis (x, y, z) of the gyroscope.	**Example**: You want to set 50°/s as threshold. 50 = 0x0032 in Hex (2 bytes) and with LSB first format 0x**3200**. So the complete command will be like “0xFE 04 **82 03 32 00** B7”

3.3 Environmental Sensor Commands

In following table the structure of the environmental sensor commands are specified. The environmental sensor is including **temperature, humidity and pressure sensors**. The light sensor is also an environmental sensor. But it has its own commands. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x83   	0x00	-	Stop streaming environmental data (temperature, humidity and pressure). This will disable the environmental sensor. Disables the sensor by putting it to suspend mode.	**Example:** The complete command will be like “0xFE 02 **83 00** 81” After this command the CISS stops streaming environmental data (temperature, humidity and pressure)
	0x01	-	Start streaming environmental data (temperature, humidity and pressure). This will enable the environmental sensors.	**Example:** The complete command will be like “0xFE 02 **83 01** 80“ After this command CISS starts streaming environmental data (temperature, humidity and pressure). The data frame format is explained in 5.2 Environmental Sensor Data Frame.
	0x02	2 Bytes - Sampling Rate	Set the sampling rate for the environmental sensors. This sampling rate is common for	The new sampling rate must be provided in seconds (s).

			all environmental sensors (temperature, humidity, pressure and light) Sampling rate must be between min: 1 second and max: 10 minutes	The data part must be in LSB first order format. **Example**: You want to set 10s sampling rate. 10 = 0x000A in Hex (2 bytes) and with LSB first format → 0x**0A00**. So the complete command will be like "0xFE 04 **83 02 0A 00** 8F"
	0x07	1 Byte Threshold (temperature)	Set the threshold of the temperature sensor in °C. The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of temperature measurement range which is between -20°C and +80°C.	**Example**: You want to set 23°C as threshold. 23 = 0x**17** in Hex with LSB first format. So the complete command will be like "0xFE 03 **83 07 17** 90"
	0x08	1 Byte Threshold (humidity)	Set the threshold of the humidity sensor in % relative Humidity (%rH). The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of humidity measurement range which is between 20 and 90%rH.	**Example**: You want to set 23%rH as threshold. 23 = 0x**17** in Hex with LSB first format. So the complete command will be like "0xFE 03 **83 08 17** 9F"
	0x09	3 Bytes - Threshold (pressure)	Set the threshold of the pressure sensor in Hectopascal (hPa). The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of pressure measurement range which is between 300 and 1100 hPa.	**Example**: You want to set 600hPa as threshold. 600 = 0x000258 in Hex (3 bytes) and with LSB first format → 0x**580200**. So the complete command will be like "0xFE 05 **83 09 58 02 00** D5"

3.4 Light Sensor Commands

In following table the structure of the light sensor commands are specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x84 	0x00	-	Stop streaming light data. This will disable the light sensor. Disables the sensor by putting it to suspend mode.	**Example:** The complete command will be like "0xFE 02 **84 00** 86" After this command the CISS stops streaming light data
	0x01	-	Start streaming light data. This will enable the light sensor.	**Example:** The complete command will be like "0xFE 02 **84 01** 87" After this command CISS starts streaming light data. The data frame format is explained in 5.2.1 Light Sensor Data Frame.
	0x02	2 Bytes - Sampling Rate	Set the sampling rate for the environmental sensors. This sampling rate is common for all environmental sensors (temperature, humidity, pressure and light) Sampling rate must be between min: 1 second and max: 10 minutes	The new sampling rate must be provided in seconds (s). The data part must be in LSB first order format. **Example**: You want to set 10s sampling rate. 10 = 0x000A in Hex (2 bytes) and with LSB first format → 0x**0A00**. So the complete command will be like "0xFE 04 **84 02 0A 00** 88"
	0x03	3 Bytes - Threshold	Set the threshold value in lux for the light sensor. The threshold is used in the operation mode "Event Detection" to monitor threshold violations. The threshold value must be in the range of light measurement range which is between 0 and 2112800 lux.	**Example**: You want to set 100 lux as threshold. 100 = 0x000064 in Hex (3 bytes) and with LSB first format 0x**640000**. So the complete command will be like "0xFE 05 **84 03 64 00 00** E6"

3.5 BLE Commands

In following table the structure of the BLE commands are specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x90 	0x00	-	Disable the BLE chip by putting it into sleep mode	**Example:** The complete command will be like "0xFE 02 **90 00** 92" After this command the CISS stops the BLE chip
	0x01	-	Enable the BLE chip by putting it into active mode	**Example:** The complete command will be like "0xFE 02 **90 01** 93" After this command CISS starts BLE chip. It starts to advertise over BLE to be connected by another device.

Note: There should be minimum 1 second gap between two enable/disable BLE commands. Please consider this in your gateway implementations.

3.6 Timestamp Commands

In following table the structure of timestamp setting command is specified. Please see the examples to understand how the command is looking like for certain settings.

Sensor ID	Command	Input	Description	Example /Remarks
0x91	-	4 Bytes (timestamp data)	Set the Unix Timestamp in seconds in CISS node. The Unix Timestamp is simply the number of seconds between a particular date and first of January 1970 (01.01.1970 00:00:00 UTC). You may use a free convertor in internet to calculate this easily.	**Example**: You want to set following time as timestamp: 25.05.2019 15:42:13 (Saturday, 25-May-19 15:42:13 UTC in RFC 2822) The Unix Time Stamp for this time is: 1558798933 This is 5CE96255 in Hex and in LBS firs format→ 5562E95C So your command will be "0xFE 05 **91 55 62 E9 5C** 16"

4 Acknowledgement Messages

CISS always replies a command with an acknowledgement message. The acknowledgement message can be positive or negative. Positive acknowledgement (ACK) means that the command is correct and executed. Negative acknowledgement (NACK) informs the user about a problem like the command is not valid, has wrong data or because of any reason could not be executed. Please see the details of the acknowledgement frames below.

4.1 Acknowledgment (ACK) Message

This is the positive acknowledgment message that tells received command was valid and it is executed successfully. Positive acknowledgement messages have a frame type/ID of “0x01”.

SOF (1 byte)	Length (1 byte)	Type/ID (1 bytes)	Executed Command Sensor ID (1 bytes)	Command Data (1 bytes)	CRC (1 byte)
0xFE (always the same)	0x03 (Length of the message without the length of the CRC code, 3 bytes)	0x01 This means the command is positively acknowledged.	XX The sensor ID of the acknowledged command is copied here.	XX The data (first byte) of the acknowledged command is copied here	XX (CRC code, it is calculated with the command data)

As an example; after the command “Start accelerometer data streaming” (0xFE 02 **80 01** 83), the CISS is supposed to send a positive acknowledgement (0xFE 03 01 **80 01** 83) and then immediately start to stream data.

If multiple commands are sent together, a single ACK will be sent by the CISS with the data part containing the response for each command. As an example; the frame 0xFE 04 **80 00 84 01** 01 contains two commands. The “80 00” says stop acceleration streaming and “84 01” says start light streaming. After this multiple command frame CISS sends a combined acknowledgement for both of the commands like 0xFE 06 01 **80 00** 01 **84 01** 03. Both of the commands are positively acknowledged.

4.2 Not-Acknowledgment (NACK) Message

The CISS send a negative acknowledgment message when the received command was not valid or due to any problem the command could not be executed. The Not-Acknowledgement (NACK) Message format is shown in the following table.

SOF (1 byte)	Length (1 byte)	Type/ID (1 bytes)	Command Sensor ID (1 bytes)	Command Error (1 bytes)	CRC (1 byte)
0xFE (always the same)	0x03 (Length of the message without the length of the CRC code, 3 bytes)	0xFF This means the command is negatively acknowledged.	XX	XX 0x7F or 0x8F or 0x9F The meaning of the command error codes are shown in following table	XX (CRC code is calculated with the command data)

The command error is one byte data that gives information about the reason of the error. All possible command error codes are shown in following table.

Command Error Codes	Meaning	Example
0x7F	Invalid command / command byte is invalid	Command: 0xFE 02 84 **0F** 89 → light sensor (0x84) has no command 0x0F. The NACK message for this command: 0xFE 03 FF 84 **7F** 07
	Invalid command / sensor type is invalid	Command: 0xFE 02 8F 00 8D → the command is invalid because there is no sensor type “8F” → NACK for this command is: 0xFE 02 FF **7F** 82
0x8F	Configuration not supported	Command: 0xFE 06 82 02 **0A 00 00 00** 8C → this command is setting the sampling rate of the gyroscope to 0000000A = 10µs which is not an allowed value → NACK message for this command is: 0xFE 03 FF 82 **8F** F1
0x9F	Command not executed	If the command could not be executed, the command part of the sent packet is replaced by 0x9F

If multiple commands are part of the same packet, and one of the command is invalid, the commands following the invalid one in the same packet will not be processed. ACK/NACK is sent until an invalid command is found in the packet. As an example: a combined command is sent as 0xFE 04 84 01 84 04 01. Here first command “84 01” means “start light streaming” which is a valid command. But the second command “84 04” is not valid. Because light sensor doesn’t have a command “04”. CISS sends a combined acknowledgement message as 0xFE 06 01 **84 01** FF **84 7F** 86 and positively acknowledge the first command and negatively acknowledge the second one.

If the same command is sent as 0xFE 04 84 04 84 01 01. The first command “84 04” is not valid and CISS will not process the second command even it is a valid one. CISS will send a NACK message as 0xFE 03 FF 84 7F 07.

Note: As an exception, When CISS is streaming data with *Accelerometer_2kHz_Mode* and a “stop accelerometer streaming” command is received, the CISS will immediately go to reset and will not send any acknowledgment.

5 Streaming and Data Frames

The CISS has eight different sensors. The Acoustics/Noise Sensor is not available via USB yet. It is available only via BLE. But all the other sensors are able to stream data via USB. It is possible to start/stop data streaming of each CISS sensor with the dedicated commands. Please see all available commands in section 3 Commands and Settings. After the starting command, the CISS streams measurement values coming from the internal sensors. The data frame structures are explained below with details.

The frames are identified with frame IDs. All available frame IDs are given in a table in the section 2.1.1 Frame Type/IDs. The frame IDs for data frames are also shown in the table below. As an example, frame ID 0x02 means that it is a data frame including accelerometer data.

5.1 Inertial Sensor Data Frames

Inertial sensors are including accelerometer, magnetometer and gyroscope. These sensors have a dedicated data frame which can be started and stopped independently. Please see the related commands to start/stop streaming in section 3 Commands and Settings.

5.1.1 How to Interpret Inertial Data Frames

As an example, let’s see the interpretation of an accelerometer data frame. The received data frame is “0xFE 07 02 87 FF 03 00 F8 FB 7D”

- Start byte: 0xFE → always same
- Length: 0x07 → 7 bytes (frame ID + data part will be 7 bytes)
- Frame ID: 0x02 → means accelerometer data frame
- Data Part: 0X87 FF 03 00 F8 FB
    - Accelerometer x-axis: 0x87 FF → LSB first FF 87 = -121 mg
    - Accelerometer y-axis: 0x03 00 → LSB first 00 03 = 3 mg
    - Accelerometer z-axis: 0xF8 FB → LSB first FB F8 = 1032 mg
- CRC Code: 7D → calculated with the data

5.1.2 Accelerometer Data Frame

Frame ID	Data	Description	Example /Remarks
0x02	6 Bytes Acc_x: 16 Bit; Acc_y: 16 Bit; Acc_z: 16 Bit	**Accelerometer Data** After the frame ID 0x02, the following 6 bytes are accelerometer data for x, y, z axis e.g. 2 bytes for each axis. The unit of the data is **mg** (mili g). If the sensor read fails, CISS sends a **failure value** of 16384, 16384, 16384 in the data.	**Example**: The received data frame looks like "0xFE 07 02 **87 FF 03 00 F8 FB** 7D" The interpretation of this frame is explained as an example in the section 4.1.1 How to Interpret Inertial Data Frame.

5.1.3 Magnetometer Data Frame

Frame ID	Data	Description	Example /Remarks
0x03	6 Bytes Mag_x: 16 Bit; Mag_y: 16 Bit; Mag_z: 16 Bit	**Magnetometer Data** After the frame ID 0x03, the following 6 bytes are magnetometer data for x, y, z axis e.g. 2 bytes for each axis. The unit of the data is **µT** (micro Tesla). If the sensor read fails, CISS sends a **failure value** of 8191, 8191, 8191 in the data.	**Example**: The received data frame looks like "0xFE 07 03 **0E 00 DC FF 10 00** 39" The interpretation of this frame is very similar like the example in the section 4.1.1 How to Interpret Inertial Data Frame.

5.1.4 Gyroscope Data Frame

Frame ID	Data	Description	Example /Remarks
0x04	6 Bytes Gyr_x (16 Bit) | Gyr_y (16 Bit) | Gyr_z (16 Bit)	**Gyroscope Data** After the frame ID 0x04, the following 6 bytes are accelerometer data for x, y, z axis e.g. 2 bytes for each axis. The unit of the data is **°/s** (Degree/Second). If the sensor read fails, CISS sends a **failure value** of 2047, 2047, 2047 in the data.	**Example**: The received data frame looks like "0xFE 07 04 **0D 00 7D 00 20 00** 53" The interpretation of this frame is very similar like the example in the section 4.1.1 How to Interpret Inertial Data Frame.

5.2 Environmental Sensor Data Frame

The temperature, pressure and humidity data are combined in one data frame. As an example, let's see the interpretation of an environmental data frame.

The received data frame is "0xFE 0B 05 D5 00 07 21 0B 06 91 83 01 00 E3"

- Start byte: 0xFE → always same
- Length: 0x0B → 11 bytes (frame IDs + data parts will be 7 bytes)
- Frame ID: 0x05 → means temperature data frame
- Temperature Data: 0xD5 00 → LSB first 0x00D5 = 213 → 213/10 = 21,3°C
- Frame ID: 0x07 → means humidity data
- Humidity Data: 0x21 0B → LSB first 0x0B21 = 2849 → 2849/100= 28,49%rH,
- Frame ID: 0x06 → means pressure data
- Pressure Data: 0x91 83 01 00 → LSB first 0x00018391 = 99217 → 99217Pa (992.17hPa)
- CRC Code: E3 → calculated with the data

The frame details are explained in the table below.

Frame ID	Data	Description	Example /Remarks
0x05	2 Bytes Temperature (16 Bit)	**Temperature Data** After the frame ID 0x05, the following 2 bytes are temperature data. The value of the data must be divided by 10 to get a °C value. The unit of the data is **°C** (Degree Celsius).	**Example**: The received data frame looks like "0xFE 0B 05 **D5 00** 07 21 0B 06 91 83 01 00 E3" The interpretation of this frame example is explained above.

		If the sensor read fails, CISS sends a **failure value** of 1000 in the data.	
0x06	4 Bytes **Pressure** 32 Bit	**Pressure Data** After the frame ID 0x06, the following 4 bytes are pressure data. The unit of the data is **Pa** (Pascal). If the sensor read fails, CISS sends a **failure value** of 120000 in the data.	**Example**: The received data frame looks like "0xFE 0B 05 D5 00 07 21 0B 06 **91 83 01 00** E3" The interpretation of this frame example is explained above.
0x07	2 Bytes **Humidity** 16 Bit	**Humidity Data** After the frame ID 0x07, the following 2 bytes are humidity data. The value of the data must be divided by 100 to get a %rH value. The unit of the data is **%rH** (% relative Humidity). If the sensor read fails, CISS sends a **failure value** of 15000 in the data.	**Example**: The received data frame looks like "0xFE 0B 05 D5 00 07 **21 0B** 06 91 83 01 00 E3" The interpretation of this frame example is explained above.

5.2.1 Light Sensor Data Frame

The light data is transmitted in its own data frame, not in the environmental data frame. The structure of the data frame is explained below with an example.

Frame ID	Data	Description	Example /Remarks
0x08	4 Bytes **Light** 32 Bit	**Light Data** After the frame ID 0x08, the following 4 bytes are light data. The unit of the data is **lux**. If the sensor read fails, CISS sends a **failure value** of 3000000 in the data.	**Example**: The received data frame looks like "0xFE 05 08 **9E 0A 00 00** 99" • Start byte: 0xFE • Length: 05 • Frame ID: 08 • Data: **9E 0A 00 00** → LSB first 0x0A9E = 2718 lux • CRC code: 99

6 Special Operation Modes

Besides standard data streaming, the CISS has three special operation modes. The special modes are explained in this chapter.

6.1 Accelerometer 2kHz Streaming Mode

The Accelerometer 2kHz Streaming Mode is a special data streaming mode for the accelerometer. In this mode all the other sensors are disabled. Only accelerometer is streaming data. The sampling rate is 2kHz which means every second ~2000 accelerometer (x, y, z) values are streamed. To start and stop following commands are used.

Command Name	Command Frame	Description
Start 2kHz Accelerometer Streaming	0xFE 06 80 02 **F4 01 00 00** 71	When CISS receives this command. It disables all the sensors except accelerometer and start to stream 2kHz accelerometer data. This command is actually setting the accelerometer sampling rate to 500µs which mean 2kHz data rate. The command data "**F4 01 00 00**" is the 4 byte sampling rate in LSB first format → 0x01F4 = 500µs
Positive Acknowledgement Message	FE 03 01 80 02 80	After the "Start 2kHz Accelerometer Streaming" command, CISS sends a positive ACK message and start immediately to stream data.
Stop 2kHz Accelerometer Streaming	FE 02 80 00 82	This is a usual stop accelerometer streaming command. It stops the streaming of 2kHz mode too.

Note: When CISS is streaming data with *Accelerometer_2kHz_Mode* and a "stop accelerometer streaming" command is received, the CISS immediately **resets itself**. In this case there is no acknowledgment message is sent for the stop command.

6.1.1 Accelerometer 2kHz Mode Data Frame

The format of the frame is shown in the table below. It starts with a starting byte (0xFE) and a length. After the length 16 data packets are transmitted in the frame. Each data packet is 7 byte. First byte is the type/ID of the accelerometer data (0x02) and following 6 bytes are the accelerometer data e.g. 2 bytes for each axis. Please see also the example frame below.

SOF (1 byte)	Length (1 byte)	Data Packet_1 (7 bytes)	Data Packet_2 (7 bytes)	Data Packet... (7 bytes)	Data Packet_16 (7 bytes)	CRC (1 byte)
0xFE	0x70 (112 bytes) (Length of the message without the length of the CRC code)	First byte is 0x02 (frame type/ID of accel. data). And following 6 bytes are accelerometer data e.g. 2 bytes for each axis.	First byte is 0x02 (frame type/ID of accel. data). And following 6 bytes are accelerometer data e.g. 2 bytes for each axis.	... ...	First byte is 0x02 (frame type/ID of accel. data). And following 6 bytes are accelerometer data e.g. 2 bytes for each axis.	XX (CRC code is calculated with the data)

Here is a 2kHz mode frame data as an example.

FE 70 02 **43 FF 1B 00 06 FC** 02 45 FF 17 00 0D FC 02 47 FF 1D 00 09 FC 02 43 FF 1B 00 04 FC 02 45 FF 19 00 FC FB 02 3F FF 1B 00 FE FB 02 45 FF 15 00 02 FC 02 43 FF 17 00 FC FB 02 47 FF 07 00 02 FC 02 43 FF 19 00 02 FC 02 47 FF 13 00 FA FB 02 49 FF 1D 00 FC FB 02 45 FF 15 00 F0 FB 02 41 FF 11 00 FC FB 02 47 FF 19 00 FC FB 02 47 FF 19 00 F8 FB **ED**

The meaning of the data is explained below.

- Start Byte: 0x**FE**
- Length: 0x70 = 112 bytes (in decimal). The frame has totally 112 byte length. Each Accelerometer data needs 6 bytes data + 1 byte ID (totally 7 bytes). This means 112/7 = 16 accelerometer data packets are sent in this frame.
- Data Packet 1: 0x02 **43 FF 1B 00 06 FC**
  - Frame ID: 0x02 → means accelerometer data
  - Data part: 0x**43 FF 1B 00 06 FC** → 6 byte data for accelerometer x, y, z axis.
- Data Packet 2: 0x02 45 FF 17 00 0D FC
- Data Packet 3:...
- ...
- ...
- Data Packet 16: 02 47 FF 19 00 F8 FB
- CRC code: 0x**ED**

6.2 Time Aggregation Mode

The time aggregation mode is special mode to reduce the data volume by aggregating the data in CISS. This mode is only available for accelerometer, gyroscope and temperature sensors. The sensor values are aggregated in time frames and minimum, maximum, mean and standard deviation of the values are transmitted. Time aggregation mode is only available via USB. The BLE is switched off in this mode.

The CISS has fixed setting for the time aggregation mode. The settings are given in the following table.

Sensor	Sampling Rate	Aggregation Time Frame
Accelerometer	100Hz (10ms)	2000ms (2 seconds)
Gyroscope	100Hz (10ms)	2000ms (2 seconds)
Temperature	1Hz (1s)	10000ms (10 seconds)

As an example, in this mode accelerometer values are sampled with 100Hz for 2 seconds and minimum, maximum, mean and standard deviation values are calculated. After that, only the calculated values are transmitted.

6.2.1 Time Aggregation Mode Commands

Command Name	Command Frame	Description
Start Time Aggregation Mode	0xFE 02 **FD 01** FE	After this command, the CISS activates the time aggregating mode and stream data.
Positive Acknowledgement Message	FE 03 01 **FD 01** FE	After the “Start Time Aggregation Mode” command, CISS sends a positive ACK message and start immediately to stream data.
Stop Time Aggregation Mode	FE 02 **FD 00** FF	This command deactivates the time aggregation mode and stops streaming data.

6.2.2 Time Aggregation Mode Data Frame

The data structures in the frame is shown in the following table. Please see also the example frame below.

Frame ID	Length	Data Structure	Description
0x7E	64 Bytes	ax_min, ax_max, ax_mean, ax_std ay_min, ay_max, ay_mean, ay_std az_min, az_max, az_mean, az_std a_min, a_max, a_mean, a_std gx_min, gx_max, gx_mean, gx_std gy_min, gy_max, gy_mean, gy_std gz_min, gz_max, gz_mean, gz_std g_min, g_max, g_mean, g_std	**Aggregated Accelerometer and Gyroscope Data** After the frame ID 0x7E, the following 64 bytes are aggregated accelerometer and gyroscope data. The unit of the accelerometer values is **mg**, and gyroscope values is **°/s**. As shown in data structure, for each axis of accelerometer calculated minimum, maximum, mean and standard deviations are transmitted. Also the same values for all 3-axis are calculated. Example: ax_min: accelerometer minimum for x-axis. a_min: minimum of the all 3-axis of the accelerometer values. gx_min: gyroscope minimum for x-axis… etc. Please see the example frame below.
0x7D	8 Bytes	t_min, t_max, t_mean, t_std	**Aggregated Temperature Data** After the frame ID 0x7D, the following 8 bytes are aggregated temperature data. The unit is **°C**. The value **must be divided by 10** to get a °C value. As shown in data structure, calculated minimum, maximum, mean and standard deviation of temperature values are transmitted. Please see the example frame below.

Example 1: The following frame is sent by CISS as time aggregating data. It includes only the accelerometer and gyroscope data. The next example includes also the temperature data.

FE 41 7E CE FD 78 03 88 FF D3 00 A9 FE FD 06 0D 01 9D 01 90 F0 38 0D A4 FC 0F 04 90 00 D3 0F 0F 05 97 02 E5 FC C1 00 DC FF 8B 00 3E FE C6 01 06 00 87 00 55 FF DE 00 11 00 38 00 00 00 40 03 64 00 B5 00 **03**

The meaning of the data is as defined below.

- Start byte: 0x**FE**
- Length: 0x41 = 65 bytes (1 byte ID + 64 bytes data)
- Frame type/ID: 7E → Time aggregation data for accelerometer and gyroscope
- Data Part (64 bytes)
  - Accelerometer x-axis → min, max, mean, std: CE FD 78 03 88 FF D3 00
  - Accelerometer y-axis → min, max, mean, std: A9 FE FD 06 0D 01 9D 01
  - Accelerometer z-axis → min, max, mean, std: 90 F0 38 0D A4 FC 0F 04
  - Accelerometer all-axis → min, max, mean, std: 90 00 D3 0F 0F 05 97 02
  - Gyroscope x-axis → min, max, mean, std: E5 FC C1 00 DC FF 8B 00
  - Gyroscope y-axis → min, max, mean, std: 3E FE C6 01 06 00 87 00
  - Gyroscope z-axis → min, max, mean, std: 55 FF DE 00 11 00 38 00
  - Gyroscope all-axis → min, max, mean, std: 00 00 40 03 64 00 B5 00
- CRC code: **03**

Example 2: The following frame is an example for time aggregation data for all three sensors. Accelerometer and gyroscope data can be interpreted like in previous example and temperature data is explained below.

FE 4A 7E 3F FF 55 FF 4B FF 04 00 44 00 61 00 52 00 04 00 EE FB 0D FC 00 FC 05 00 07 04 25 04 13 04 05 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 7D D4 00 D7 00 D6 00 00 00 **18**

The meaning of the data is as defined below.

- Start byte: 0x**FE**
- Length: 0x4A = 74 bytes (1 byte ID + 64 bytes accelerometer and gyroscope data + 1 byte ID + 8 byte temperature data)
- Frame type/ID: 7E → Time aggregation data for accelerometer and gyroscope
- Data Part for accelerometer and gyroscope data (64 bytes)
  - See explanation in the previous example
- Frame type/ID: 7D → Time aggregation data for temperature data
- Data Part for temperature data (8 bytes)
  - Temperature → min, max, mean, std: D4 00 D7 00 D6 00 00 00
- CRC code: **18**

6.3 Event Detection Mode

The event detection mode is used for threshold monitoring applications. In this mode, the measured values will be compared to a configured threshold. When a threshold violation happens, CISS sends an overshoot or undershoot warning. When the threshold is exceeded by an increasing measurement value, this means overshoot. And when the measurement value decrease and pass again to lower values than the threshold, this is considered as undershoot.

In this mode the CISS transmits only a bit coded (bitmask) value representing the threshold violation. See below the data frame explanation.

Note: Before starting this mode, the CISS sensors must be configured with related commands. The user should configure e.g. sampling rate, thresholds etc. If a certain sensor should be disabled for event detection, the threshold value can be set out of the range. CISS will not detect a threshold violation in this case.

After starting the event detection mode, if a reconfiguration is needed (e.g. other sensor selection), first the event detection mode must be stopped. This will disable all sensors. The thresholds for previously selected sensors are retained but the sensors themselves are disabled. Then the configuration can be done e.g. thresholds to the respective sensors. And finally the event detection mode can be started again.

6.3.1 Event Detection Mode Commands

Command Name	Command Frame	Description
Start Event Detection Mode	0xFE 02 **FC 01** FF	After this command, the CISS activates the event detection mode and stream data.
Positive Acknowledgement Message	0xFE 03 01 **FC 01** FF	After the “Start Event Detection Mode” command, CISS sends a positive ACK message and start immediately to stream data.
Stop Event Detection Mode	0xFE 02 **FC 00** FE	This command deactivates the event detection mode and stops streaming data.

6.3.2 Event Detection Mode Data Frame

<table>
<tr><th>Frame ID</th><th>Length</th><th>Data Structure Description / Bitmask</th></tr>
<tr><td>0x7A</td><td>2 Bytes</td><td>Event Detection Data / Bitmask
After the frame ID 0x7A, the following 2 bytes (16 Bits) are bit coded event detection data. The meaning of each bit is explained below in the table. Acoustic/Noise sensor is not available via USB. So last 2 bits are reserved. Please see the example frames below.

<table>
<tr><td></td><td colspan="2">Noise</td><td colspan="2">Light</td><td colspan="2">Pressure</td><td colspan="2">Humidity</td><td colspan="2">Temperature</td><td colspan="2">Magnetometer</td><td colspan="2">Gyroscope</td><td colspan="2">Acceleration</td></tr>
<tr><td>Bit</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>Descript.</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td><td colspan="2">00: Unchanged
01: Overshoot
11: Undershoot</td></tr>
</table>
</td></tr>
</table>

In the following table there are several examples with the event detection frame.

Event Frame Example	Data	Bitmask (16 bits)	Meaning
0xFE 03 7A **01 00** 78	0x0100 → LSB first → 0x0001	0000 0000 0000 0001	Accelerometer Overshoot
0xFE 03 7A **04 00** 7D	0x0400 → LSB first → 0x0004	0000 0000 0000 0100	Gyroscope Overshoot
0xFE 03 7A **0C 00** 75	0x0C00 → LSB first → 0x000C	0000 0000 0000 1100	Gyroscope Undershoot
0xFE 03 7A **00 10** 69	0x0010 → LSB first → 0x1000	0001 0000 0000 0000	Light Overshoot
0xFE 03 7A **00 30** 49	0x0030 → LSB first → 0x3000	0011 0000 0000 0000	Light Undershoot

For further assistance, please send an e-mail to: support@bosch-connectivity.com

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