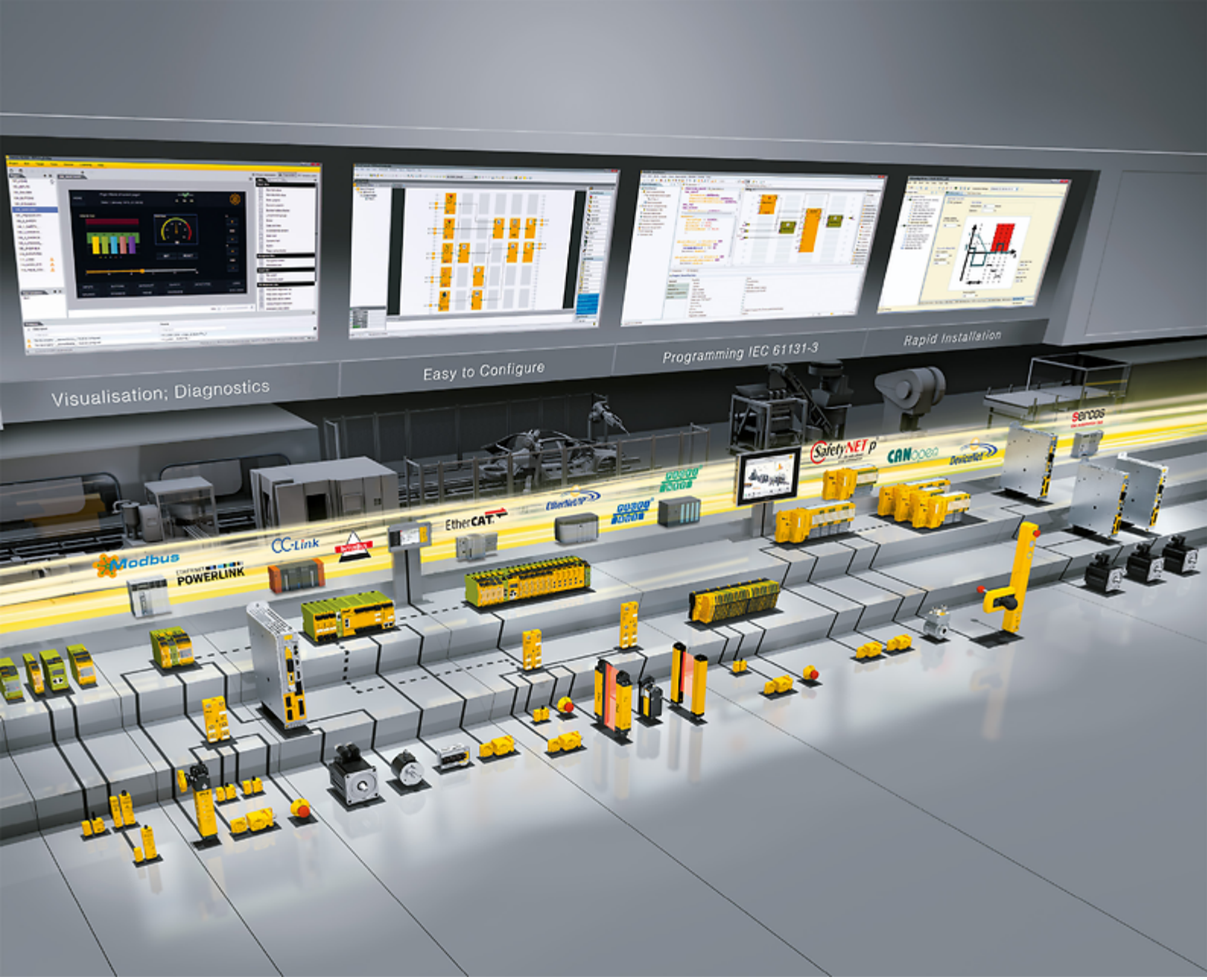


PSENscan UDP Communication

PILZ
THE SPIRIT OF SAFETY

- PSEN sensor technology

Shortform-1005879-EN-01

This document is the original document.

Where unavoidable, for reasons of readability, the masculine form has been selected when formulating this document. We do assure you that all persons are regarded without discrimination and on an equal basis.

1 Introduction

1.1 About this Manual

This Manual is provided for users seeking advanced technical information, including connection, programming, maintenance and specifications. The operating manual and other publications associated with this product can be downloaded free of charge from the website listed on the back cover of this manual.

1.2 Definition of symbols

Information that is particularly important is identified as follows:

DANGER!

This warning must be heeded! It warns of a hazardous situation that poses an immediate threat of serious injury and death and indicates preventive measures that can be taken.

WARNING!

This warning must be heeded! It warns of a hazardous situation that could lead to serious injury and death and indicates preventive measures that can be taken.

CAUTION!

This refers to a hazard that can lead to a less serious or minor injury plus material damage, and also provides information on preventive measures that can be taken.

NOTICE

This describes a situation in which the product or devices could be damaged and also provides information on preventive measures that can be taken. It also highlights areas within the text that are of particular importance.

INFORMATION

This gives advice on applications and provides information on special features.

2 UDP based Monitoring

Please note that this document applies to the following models of Safety laser scanner:

- PSEN sc L 3.0/5.5 08-12
- PSEN sc M 3.0/5.5 08-12
- PSEN sc M 3.0/5.5 08-17
- PSEN sc ME 5.5 08-17

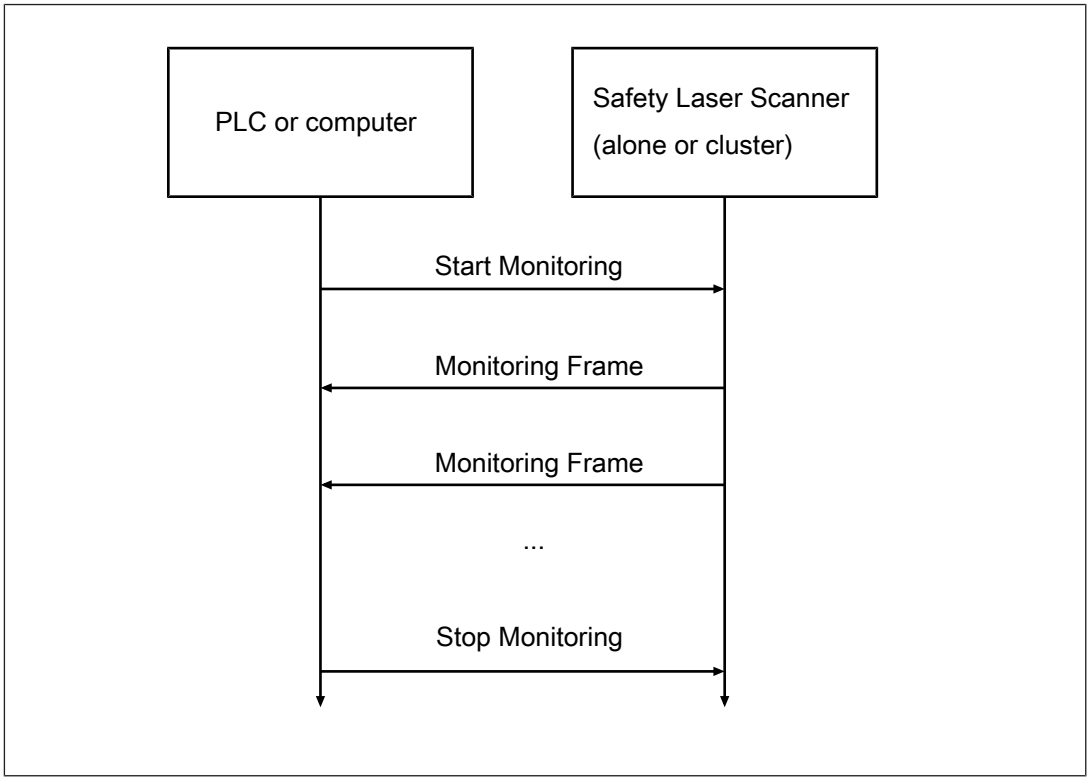
Master devices (PSEN sc M, PSEN sc ME) can be connected to up to 3 Subscriber devices (PSEN sc S) in a cascade configuration. In this case, the system composed of a Master device and one to three Subscriber devices will be referred to as “cluster”.

WARNING!

Advanced Measurement data may only be used for general monitoring and control activities. Do NOT use this data for safety-related applications.

3 UDP based Monitoring for Safety laser scanner

Safety laser scanner supports a UDP client-server communication over Ethernet (up to 100Mbps) that allows a PLC or computer (client) to run the Safety laser scanner monitoring function on the Safety laser scanner (server).



Activating the monitoring function makes it possible to receive measurement distance data and information about the status of the Safety laser scanner. Information is sent to the PLC or computer by a continuous flow of UDP packets.

Moreover, if multiple scanner devices are connected to each other as a cluster, the main unit (Master) is responsible for collecting and sending all monitoring frames to the client.

The data sent from the Master device to the client for each complete scan are structured in 6 monitoring frames (see Monitoring Frame (from Device to Client) [📖 13]). If Subscriber devices are connected to the Master device, an additional monitoring frame is sent for each one of them.

3.1 Client Disconnection

As UDP is a connectionless protocol, disconnecting the client from the network (i.e. unplugging the Ethernet cable, or powering off the client) does not result in stopping the monitoring function: if the client's IP has not changed, reconnecting the client to the network allows the monitoring frames to reach the client again. If the client's IP has changed (or the client has been replaced with another one), frames do not reach the client since they are still sent to the previous IP address and port.

4 Command List

Advanced measurement protocol includes the following messages:

- Start request
- Start reply
- Stop request
- Stop reply
- Monitoring frame

NOTICE

Appendix A provides some examples of the available messages described in this chapter.

4.1 Start Request (from Client to Device)

The Start command must be sent to the Safety laser scanner IP address using UDP port 3000. This command provides the device with information to be sent during monitoring.

NOTICE

We recommend that the Start command be sent using PSENscan Configurator (Options > Expanded monitoring). This ensures that the message is correct and that the information requested meets the communication band.

The UDP payload uses the following format. Unless otherwise indicated, the byte order is little endian.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x00	4	CRC	A CRC32 of all the following fields. See CRC Computation [📖 24]
0x04	4	SEQ NUMBER	Sequence number of the message
0x08	8	RESERVED	Use all zeros
0x10	4	OP CODE	Operation Code (START 0x35)
0x14	4	IP	Client IP address. Byte order: big endian.
0x18	2	PORT	Client communication port
0x1A	1	DEVICE ENABLED	Enables or disables the monitoring message on one or more devices [a]. **Note**: The Master device is always active, therefore its default value is (1000).
0x1B	1	INTENSITY ENABLED	Enables or disables the intensity field on a device [a].

OFFSET	LENGTH	FIELD	DESCRIPTION
0x1C	1	POINT IN SAFETY ENABLED	Enables or disables the Point in Safety field, which specifies whether the point of a device lies within the Safety Area [a].
0x1D	1	ACTIVE ZONE- SET ENABLED	Enables or disables the field that indicates which Zone set is active on the device [a].
0x1E	1	I/O PIN ENABLED	Enables or disables the field that shows the configured I/O pins [a].
0x1F	1	SCAN COUNTER ENABLED	Enables or disables the scan counter field [a].
0x20	1	SPEED ENCODER ENABLED	Enables or disables the field that specifies whether the encoder is active. As the encoder can only be enabled on the Master device (model Safety laser scanner-PSEN sc ME), this 1-byte mask will be (1111) if the encoder is active, or (0000) if the encoder is not active.
0x21	1	DIAGNOSTICS ENABLED	Enables diagnostics on the selected device [a].
0x22	2	MASTER START ANGLE	Indicates the start angle of the Master device expressed in tenths of a degree [b].
0x24	2	MASTER END ANGLE	Indicates the end angle of the Master device expressed in tenths of a degree [c].
0x26	2	MASTER RESOLUTION	Indicates the angle resolution of the Master device expressed in tenths of a degree. Example: to sample an angle every 0.1°, this value must be 0.1 x 10 = **1**
0x28	2	SUBSCRIBER 1 START ANGLE	Indicates the start angle of the Subscriber 1 device expressed in tenths of a degree [b]. **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.
0x2A	2	SUBSCRIBER 1 END ANGLE	Indicates the end angle of the Subscriber1 device expressed in tenths of a degree [c]. **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x2C	2	SUB-SCRIBER 1 RESOLU-TION	Indicates the resolution of the Subscriber 1 device expressed in tenths of a degree. Example: to sample an angle every 5.0°, resolution value is 5.0 x 10 = **50** **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.
0x2E	2	SUB-SCRIBER 2 START ANGLE	Indicates the start angle of the Subscriber 2 device expressed in tenths of a degree [b]. **Note**: If the DEVICE ENABLED mask of Subscriber 2 is false (value = 0), this field will have a value = 0.
0x1C	1	POINT IN SAFETY EN-ABLED	Enables or disables the Point in Safety field, which specifies whether the point of a device lies within the Safety Area [a].
0x1D	1	ACTIVE ZONE- SET ENABLED	Enables or disables the field that indicates which Zone set is active on the device [a].
0x1E	1	I/O PIN EN-ABLED	Enables or disables the field that shows the configured I/O pins [a].
0x1F	1	SCAN COUNTER ENABLED	Enables or disables the scan counter field [a].
0x20	1	SPEED EN-CODER EN-ABLED	Enables or disables the field that specifies whether the encoder is active. As the encoder can only be enabled on the Master device (model Safety laser scanner-M5-E-1708), this 1-byte mask will be (1111) if the encoder is active, or (0000) if the encoder is not active.
0x21	1	DIA-GNOSTICS ENABLED	Enables diagnostics on the selected device [a].
0x22	2	MASTER START ANGLE	Indicates the start angle of the Master device expressed in tenths of a degree [b].
0x24	2	MASTER END ANGLE	Indicates the end angle of the Master device expressed in tenths of a degree [c].
0x26	2	MASTER RESOLU-TION	Indicates the angle resolution of the Master device expressed in tenths of a degree. Example: to sample an angle every 0.1°, this value must be 0.1 x 10 = **1**

OFFSET	LENGTH	FIELD	DESCRIPTION
0x28	2	SUB-SCRIBER 1 START ANGLE	Indicates the start angle of the Subscriber 1 device expressed in tenths of a degree [b]. **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.
0x2A	2	SUB-SCRIBER 1 END ANGLE	Indicates the end angle of the Subscriber 1 device expressed in tenths of a degree [c]. **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.
0x2C	2	SUB-SCRIBER 1 RESOLU-TION	Indicates the resolution of the Subscriber 1 device expressed in tenths of a degree. Example: to sample an angle every 5.0°, resolution value is 5.0 x 10 = **50** **Note**: If the DEVICE ENABLED mask of Subscriber 1 is false (value = 0), this field will have a value = 0.
0x2E	2	SUB-SCRIBER 2 START ANGLE	Indicates the start angle of the Subscriber 2 device expressed in tenths of a degree [b]. **Note**: If the DEVICE ENABLED mask of Subscriber 2 is false (value = 0), this field will have a value = 0.
0x30	2	SUB-SCRIBER 2 END ANGLE	Indicates the end angle of the Subscriber 2 device expressed in tenths of a degree [c]. **Note**: If the DEVICE ENABLED mask of Subscriber 2 is false (value = 0), this field will have a value = 0.
0x32	2	SUB-SCRIBER 2 RESOLU-TION	Indicates the resolution of the Subscriber 2 device expressed in tenths of a degree. Example: to sample an angle every 5.0°, resolution value is 5.0 x 10 = **50** **Note**: If the DEVICE ENABLED mask of Subscriber 2 is false (value = 0), this field will have a value = 0.
0x34	2	SUB-SCRIBER 3 START ANGLE	Indicates the start angle of the Subscriber 3 device expressed in tenths of a degree [b]. **Note**: If the DEVICE ENABLED mask of Subscriber 3 is false (value = 0), this field will have a value = 0.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x36	2	SUB-SCRIBER 3 END ANGLE	Indicates the end angle of the Subscriber 3 device expressed in tenths of a degree [c]. **Note**: If the DEVICE ENABLED mask of Subscriber 3 is false (value = 0), this field will have a value = 0.
0x38	2	SUB-SCRIBER 3 RESOLU-TION	Indicates the resolution of the Subscriber 3 device expressed in tenths of a degree. Example: to sample an angle every 5.0°, resolution value is 5.0 x 10 = **50** **Note**: If the DEVICE ENABLED mask of Subscriber 3 is false (value = 0), this field will have a value = 0.
TOTAL	**58 BYTES**		

a. 1-byte mask. Only the last 4 bits (little endian) are used, each of which represents a device. For example, (1000) only enables the Master device, while (1010) enables both the Master and the second Subscriberdevice.

b. The start angle must have a minimum value of 0 degrees and must not exceed the end angle.

c. The end angle must have a maximum value of 275 degrees and must not be less than the start angle.

4.2 Start Reply (from Device to Client)

The UDP uses the following format. Unless otherwise indicated, the byte order is little endian.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x00	4	CRC	A CRC32 of all the following fields. See CRC Computation [24]
0x04	4	RESERVED	-
0x08	4	OP CODE	Operation Code (START 0x35).
0x0C	4	RES CODE	Operation result. If the message is accepted, the returned value is 0x00. If the message is refused, the returned value is 0xEB. If the CRC is not correct, the device will not send any message.
TOTAL	**16 BYTES**		

4.3 Stop Request (from Client to Device)

The Stop command must be sent to the Safety laser scanner IP address using UDP port 3000.

The UDP uses the following format. Unless otherwise indicated, the byte order is little endian.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x00	4	CRC	A CRC32 of all the following fields. See CRC Computation [📖 24]
0x04	12	RESERVED	Use all zeros
0x10	4	OP CODE	Operation Code (START 0x36).
TOTAL	**20 BYTES**		

4.4 Stop Reply (from Device to Client)

The UDP uses the following format. Unless otherwise indicated, the byte order is little endian.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x00	4	CRC	A CRC32 of all the following fields. See CRC Computation [📖 24]
0x04	4	RESERVED	-
0x08	4	OP CODE	Operation Code (START 0x36).
0x0C	4	RES CODE	Operation result. If the message is accepted, the returned value is 0x00. If the message is refused, the returned value is 0xF7. If the CRC is not correct, the device will not send any message.
TOTAL	**16 BYTES**		

4.5 Monitoring Frame (from Device to Client)

Monitoring frames are sent by the Safety laser scanner after a Start command. Monitoring frames are sent to the IP address and UDP port specified by the Start command itself.

Each monitoring frame is always composed of:

- 6 messages for the Master device
- 1 message for each Subscriber device

Each message is composed of the following elements:

- The same information is always stored in the first 19 bytes.
- The remaining bytes are variable in number and depend on the configuration sent with the Start command. Each configuration sent with the Start command will prompt the system to send data in the monitoring frame. For more information on decoding additional information, refer to Additional Information [📖 16].
- The end of the message is given by either the length or the end message header ID with LEN 0.

NOTICE

Measurement data are always included in the frame (they are not optional).

The UDP uses the following format. Unless otherwise indicated, the byte order is little endian.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x00	4	DEVICE STATUS	Bit mask representing the device status (see Device Status [📖 14]
0x04	4	OP CODE	Constant 0xCA.
0x08	4	WORKING MODE	Online = 0x00 Offline = 0x01 Offline test = 0x02
0x0C	4	TRANSACTION TYPE	PSENscan Configurator monitoring transaction = 0x05.
0x10	1	SCANNER ID	Scanner identification: 0 = master/standalone [1..3] = subscribers.
0x11	2	FROM THETA	From Theta angle.
0x13	2	RESOLUTION	Angle resolution selected during the configuration phase. The value is expressed in tenths of degree.

OFFSET	LENGTH	FIELD	DESCRIPTION
0x15	Variable	ADDITIONAL INFORMA-TION	Additional information that depends on start configuration.

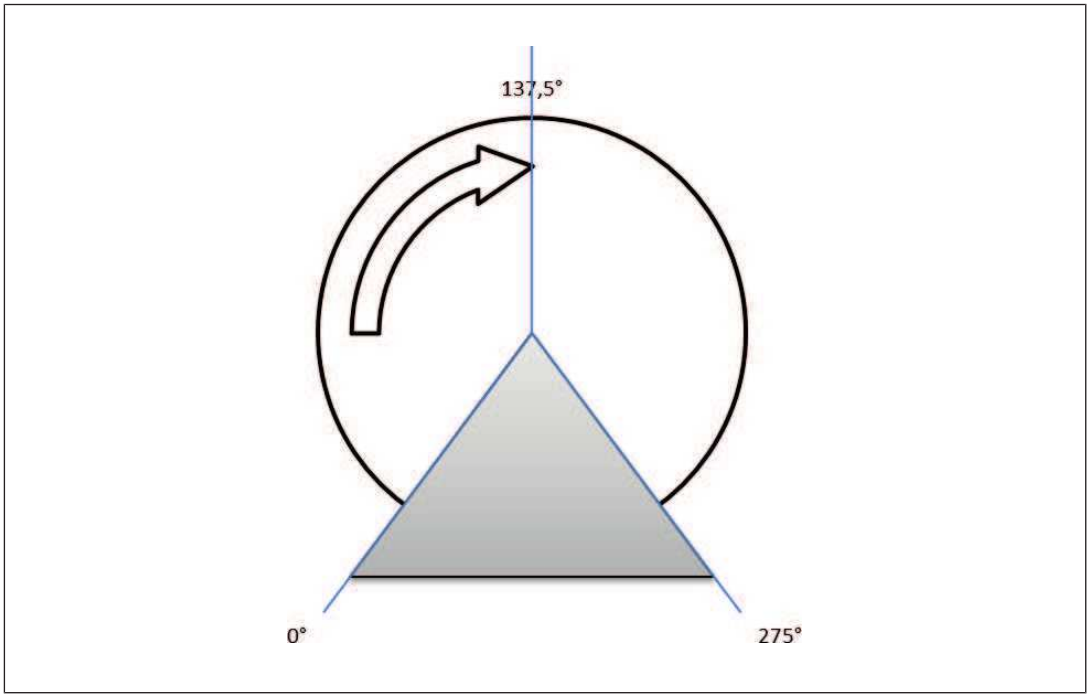
4.5.1 Device Status

The Device Status bitmask can be decoded according to the following table:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
OSSD1	OSSD2	OSSD3	WARN1	WARN2	REF_PTS	-	-

4.5.2 FromTheta

The following diagram shows the reference system of the “FromTheta” field:



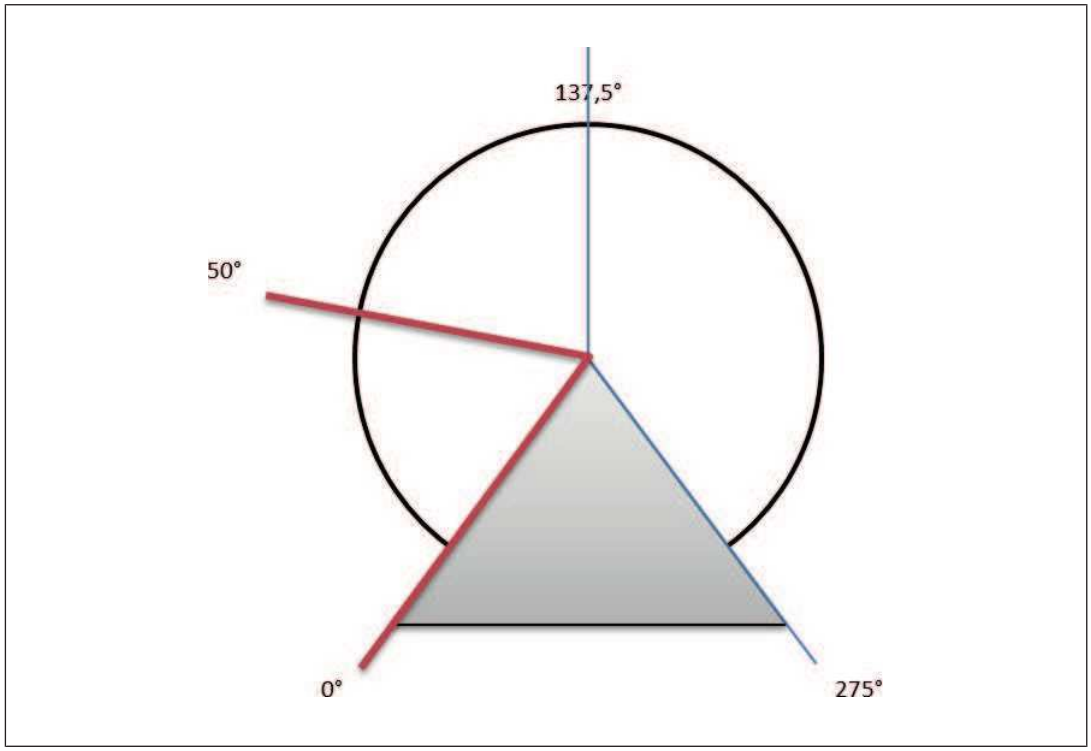
The formula to be used to compute the angular region interested by the measures of a frame is:

Start angle = "FromTheta" /10 [degrees]

End angle = ("FromTheta" + ("Resolution" * "Number of Samples")) /10 [degrees]

E.g.: a frame with “FromTheta” equal to 0, “Resolution” equal to 1 and “Number of Samples” equal to 500 covers the angular region from 0 to 50°.

At the end of the end angle the formula changes to: (end_angle-1)/10 degrees



4.5.3 Additional Information

The “Additional Information” field is variable in content and size. It consists of a vector of the following structures:

HeaderID	HeaderLENinbytes	Payload
(1 byte)	(2 bytes)	(variable length)

The following tables show how the client can decode all possible structures:

I/O PIN		
ID	**Length**	**Payload**
0x01	62	Area representing the state of the cluster input and output pins (see I/O Pin State [19])

SCAN COUNTER		
ID	**Length**	**Payload**
0x02	4	Counter indicating the number of rounds that the motor has performed since power-up. It can be used as a timestamp for the data of the same frame.

ZONE SET		
ID	**Length**	**Payload**
0x03	1	Zone set currently active on the cluster. The zone set number is 0-based (i.e. “Zone set 0” refers to the first zone set).

DIAGNOSTICS		
ID	**Length**	**Payload**
0x04	40	Area representing diagnostics fault errors (see Diagnostics [22])

MEASURES		
ID	**Length**	**Payload**
0x05	Variable	An array of little endian 16-bit unsigned integers representing distances in millimeters. The actual number of samples is given by “Length” divided by two.

INTENSITY		
ID	**Length**	**Payload**
0x06	Variable	An array of 16-bit unsigned integers representing the received normalized signal intensities. The actual number of samples is given by “Length” divided by two.

NOTICE

The two most significant bits (15 and 14) represent the channel, while the others (13:0) represent the intensity, as illustrated in the table below.

	Byte 1		**Byte 0**
	15 14		13 12 11 10 9 8 7 6 5 4 3 2 1 0
	Channel		**Energy Data**
Diffusive	0	0	
Auxiliary	0	1	
Reflective	1	0	
Intensity data not available	1	1	

ENCODER		
ID	**Length**	**Payload**
0x07	4	Two 16-bit unsigned integers representing speeds in cm/s read from the encoders. Byte order is big endian. This value is expressed in cm/s.

POINT IN SAFETY		
ID	**Length**	**Payload**
0x08	Variable	A bitmask representing all points for which a measure has been requested. If the point is falling in the active safety area, then bit=1, otherwise bit=0.

FRAME END BEFORE STANDARD LENGTH		
ID	**Length**	**Payload**
0x09	0	Field that identifies the end of the frame (no more data available).

NOTICE

I/O PIN, DIAGNOSTICS, and SCAN COUNTER messages are repeated on every frame, if active.

NOTICE

Encapsulated messages are ordered according to their enumeration. For example, if I/O PIN and MEASURES are active, the message will first indicate the I/O PIN data.

4.5.4 I/O Pin State

The input state area is split into two sections: physical inputs and logical inputs.

Since inputs may change at a frequency higher than the message transmission, the physical input section consists of three identical records that store the last three sets of input values. Each record is described by the following table:

LENGTH	FIELD	DESCRIPTION
4	RESERVED	-
10	PHYSICAL INPUT SIGNALS	Byte array representing the physical input values (see below)

The physical input signals array can be decoded according to the following tables. Bytes from 0 to 5 are unused. Byte 9 is unused, as well.

Byte 6:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Zone set Switching Input 8	Zone set Switching Input 7	Zone set Switching Input 6	Zone set Switching Input 5	Zone set Switching Input 4	Zone set Switching Input 3	Zone set Switching Input 2	Zone set Switching Input 1

Byte 7:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Override 12	Override 11	Muting 12	Muting 11	Muting Enable 1	Restart 1	-	Reset

Byte 8:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
EDM 2	Override 22	Override 21	Muting 22	Muting 21	Muting Enable 2	Restart 2	EDM 1

The logical input section is described by the following table:

LENGTH	FIELD	DESCRIPTION
4	RESERVED	-
8	LOGICAL INPUT SIGNALS	Byte array representing the physical input values.

Byte 0: indicates the enabled Zone Set in the Safety Laser Scanner (from zone 0 to zone 69).

Bytes from 1 to 3 are not used.

Byte 4:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Zone set Switching Input 2	Zone set Switching Input 1	Reserved	Override 2 Activated	Override 1 Activated	Reserved	Muting 2 Activated	Muting 1 Activated

Byte 5:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Reserved	Reset Activated	Zone set Switching Input 8	Zone set Switching Input 7	Zone set Switching Input 6	Zone set Switching Input 5	Zone set Switching Input 4	Zone set Switching Input 3

Byte 6:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Correct activation sequence of Muting 2 Pins	Muting Enable 2 Activated	Restart 2 Activated	Reserved	Correct activation sequence of Override 1 Pins	Correct activation sequence of Muting 1 Pins	Muting Enable 1 Activated	Restart 1 Activated

Byte 7:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved	Correct activation sequence of Override 2 Pins

Zone Set Switching bits in bytes 4 and 5 are the values of the physical zone set switching inputs of the active Zone Set in the Safety Laser Scanner.

Muting 1 Activated, Muting 2 Activated, Override 1 Activated and Override 2 Activated bits in byte 4 indicate when the specific function is “on” or “off”.

Reset Activated, Restart 1 Activated, Restart 2 Activated, Muting Enable 1 Activated and Muting Enable 2 Activated bits in bytes 5 and 6 are set when the corresponding pins are considered valid and stable from the device.

Bit 2, Bit 3, Bit 7 of byte 6 and Bit 0 of byte 7 indicate when the sequences of pins of muting and override functions are valid according to the product requirements.

The output section is described by the following table:

LENGTH	FIELD	DESCRIPTION
4	RESERVED	-
4	OUTPUTS	Bitmask representing output values (see below).

The output bitmask can be decoded according to the following tables.

BIT31	BIT30	BIT29	BIT28	BIT27	BIT26	BIT25	BIT24
-	-	-	REFERENCE POINTS VIOLATION	-	-	-	-

BIT23	BIT21	BIT21	BIT20	BIT19	BIT18	BIT17	BIT16
-	-	-	-	-	-	-	-

BIT15	BIT14	BIT13	BIT12	BIT11	BIT10	BIT9	BIT8
-	-	-	-	-	-	-	-

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Warning 2 intrusion	Warning 1 intrusion	-	Safety 3 intrusion	INTERLOCK 2	Safety 2 intrusion	INTERLOCK 1	Safety 1 intrusion

These bits are the cumulative intrusions of all the devices of which the Safety Laser Scanner network is composed (it is the Safety Laser Scanner system status).

NOTICE

Once the monitoring function is active, the configuration can be modified by sending a Stop command first, and then a new Start command with the new configuration.

4.5.5 Diagnostics

The following table shows the structure of the diagnostic payload:

LENGTH	FIELD	DESCRIPTION
4	RESERVED	-
36	DIAGNOSTIC INFORMATION	Byte array representing diagnostic information (see below).

In the diagnostic information field, each device (starting from the master) is assigned with 9 bytes. Those bytes can be decoded according to the following tables, in which:

Bit =1: Error; Bit = 0 No error.

Byte 0:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
OSSD1 Overcurrent / Short circuit	Short circuit at least between two OSSDs	Integrity check problem on any OSSD	Internal error	Internal error	Internal error	Internal error	Internal error

Byte 1:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Window cleaning alarm	Power supply problem	Network problem	Dust circuit failure	Internal error	Internal error	-	OSSD2 Overcurrent / Short circuit

Byte 2:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Measure problem	Internal error	Internal error	Internal error	Incoherence data	Zone: invalid input transition or integrity	Zone: invalid input configuration / connection	Window cleaning warning

Byte 3:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Internal communication problem	Internal error	Internal error	Generic error	Display communication problem	Internal error	Internal error	Temperature measurement problem

Byte 4:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
Internal error	Internal error	EDM2 Error	EDM1 Error	Configuration error	Out of range error	Temperature range error	Internal error

Byte 5:

BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
-	-	-	-	Internal error	Internal error	Encoder: generic error	Encoder: Out of Range

Bytes from 6 to 8 are not used.

NOTICE

Once the monitoring function is active, the configuration can be modified by sending a Stop command first, and then a new Start command with the new configuration.

4.6 CRC Computation

The following CRC32 is used to detect accidental changes to raw data while exchanging frames between client and server:

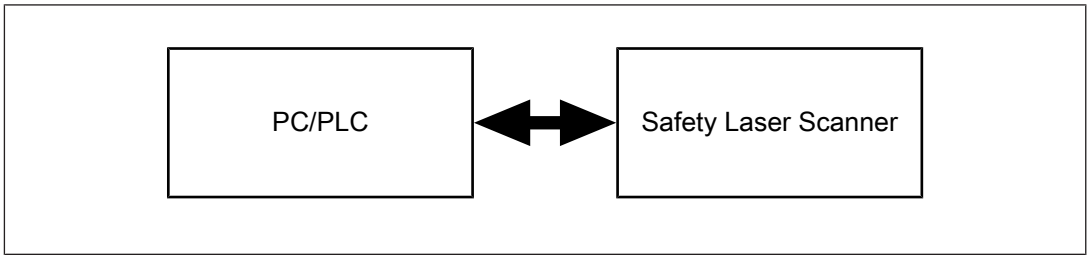
PARAMETER	VALUE
Order	32
Polynomial	0x04C11DB7
Initial Value	0xFFFFFFFF
Final XOR Value	0xFFFFFFFF

Source code example:

```
public class CRC32
{
    private const UInt32 ORDER = 32;
    private const UInt32 TOP_BIT = 0x80000000;
    private const UInt32 TABLE_SIZE = 256;


    private const UInt32 polynomial = 0x04c11db7;
    public const UInt32 Initial = 0xffffffff;
    private const UInt32 finalXor = 0xffffffff;
    private static UInt32[] table = new UInt32[TABLE_SIZE];
    private static bool isTableGenerated = false;

    public CRC32()
    {
        generateTable();
    }

    public UInt32 compute(byte[] data)
    {
        return finalize(computeIncremental(Initial, data));
    }

    public UInt32 computeIncremental(UInt32 crc, byte[] data)
    {
        UInt32 i;
        byte b, pos;

        for (i = 0; i < data.Length; i++)
        {
            b = reflect8(data[i]);

            pos = (byte)((crc ^ (b << 24)) >> 24);
            crc = (UInt32)((crc << 8) ^ ((UInt32)table[pos]));
        }

        return crc;
    }

    public UInt32 finalize(UInt32 crc)
    {
        UInt32 result;

        result = reflect32(crc) ^ finalXor;
        if (result == 0xffffffff) result ^= 0x1;
        return result;
    }

    private static void generateTable()
    {
        UInt32 bit, div, curr;

        if (isTableGenerated)
            return;

        for (div = 0; div < TABLE_SIZE; div++)
        {

            curr = div << 24;
            for (bit = 0; bit < 8; bit++)
        {
            if ((curr & TOP_BIT) != 0)
            {
                curr <<= 1;
                curr ^= polynomial;
            }
            else
            {
                curr <<= 1;
            }
        }

        table[div] = curr;
    }

    isTableGenerated = true;
}

private static byte reflect8(byte b)
{
    byte r, i;

    r = 0;
    for (i = 0; i < 8; i++)
    {
        if ((b & (1 << i)) != 0) r |= ((byte)(1 << (7 - i)));
    }

    return r;
}

private static UInt32 reflect32(UInt32 b)
{
    int r, i;

    r = 0;
    for (i = 0; i < 32; i++)
    {
        if ((b & (1 << i)) != 0) r |= ((int)(1 << (31   i)));
    }

    return (uint)r;
}
}
```

5 Data Processing Time

The time to process data for UDP command communications is as follows.



The communication time between the Safety laser scanner and other devices (i.e. PLC or computer) differs depending on your communication environment.

The time elapsed from the acquisition by the Safety laser scanner of the first measure contained in a frame and the expedition of the corresponding UDP frame depends on the actual scanner and on the number of connected Safety laser scanner devices. Please refer to the following table.

SCANNER ID VALUE	NO SUBSCRIBER CONNECTED	1 SUBSCRIBER CONNECTED	2 SUBSCRIBERS CONNECTED	3 SUBSCRIBERS CONNECTED
0 (Master)	2 ms	2 ms	2 ms	2 ms
1 (Subscriber #1)	NA	30 + 2 ms	30 + 2 ms	30 + 2 ms
2 (Subscriber #2)	NA	NA	30 + 4 ms	30 + 4 ms
3 (Subscriber #3)	NA	NA	NA	30 + 6 ms

6 Distance Accuracy vs. Target Reflectivity

Considering a distance range from 0 to 5500 mm, the following table shows how distance measurement accuracy is affected by target's reflectivity:

TARGET REFLECTIVITY	TYPICAL DISTANCE ERROR
1.8 %	± 30 mm
18 %	± 24 mm
90 %	± 21 mm
1000 %	± 12 mm

7 Protocol Examples

The following examples are based on firmware version 3.1.0 assuming that the cluster is always composed of 1 Master and 3 Subscriber devices.

7.1 Monitoring started via PSENscan Configurator

7.1.1 Start request

Figure 1 shows a start command request performed by the PSENscan Configurator software.

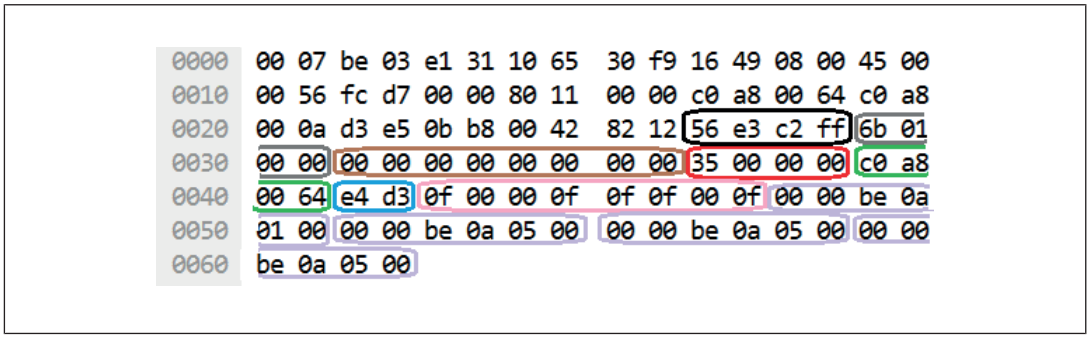


Fig.: 1 - Start request

The colors used in the figure have the following meaning:

- Black: CRC of the command (format: little endian)
- Gray: sequence number (format: little endian)
- Brown: reserved (empty)
- Red: operation code (format: little endian; in this example, the operation code 0x35 identifies the start command)
- Green: IP address of the receiver client (format: big endian; in this example, the IP address is 192.168.0.100)
- Blue: port number (format: big endian; in this example, the port number is 58579)
- Pink: enabled bit (in this example, zone set, I/O, scan counter, and diagnostics are enabled on four devices). Measures are enabled by default.
- Purple: each slot represents the start angle, stop angle, and resolution for each device. Each value is 2-byte long and expressed in tenth of degree. The format is little endian:
  - Master (first slot): start angle is 0, stop angle is 2750 (0x0ABE), resolution is 1
  - Subscribers (second, third, and fourth slots): start angle is 0, stop angle is 2750, resolution is 5.

7.1.2 Start reply

Figure 2 shows a start command response.

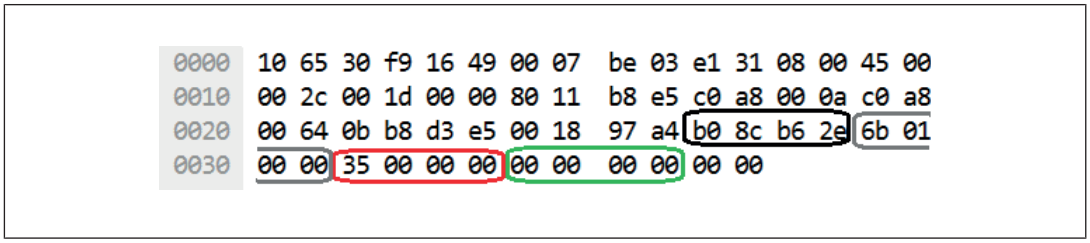


Fig.: 2 - Start reply

The colors used in the figure have the following meaning:

- Black: CRC of the command (format: little endian)
- Gray: sequence number (format: little endian)
- Red: operation code (format: little endian)
- Green: operation result (in this case all zeros mean no error)

7.1.3 Monitoring frame created by the Master device

The Master device divides its 275° into six zones: five zones of 50° each and the last zone of 25°. Each zone corresponds to a different frame (the Master device needs a total of six frames to transfer a complete set of measures).

Figure 3 shows the Master frame for the first zone (0 - 50°).

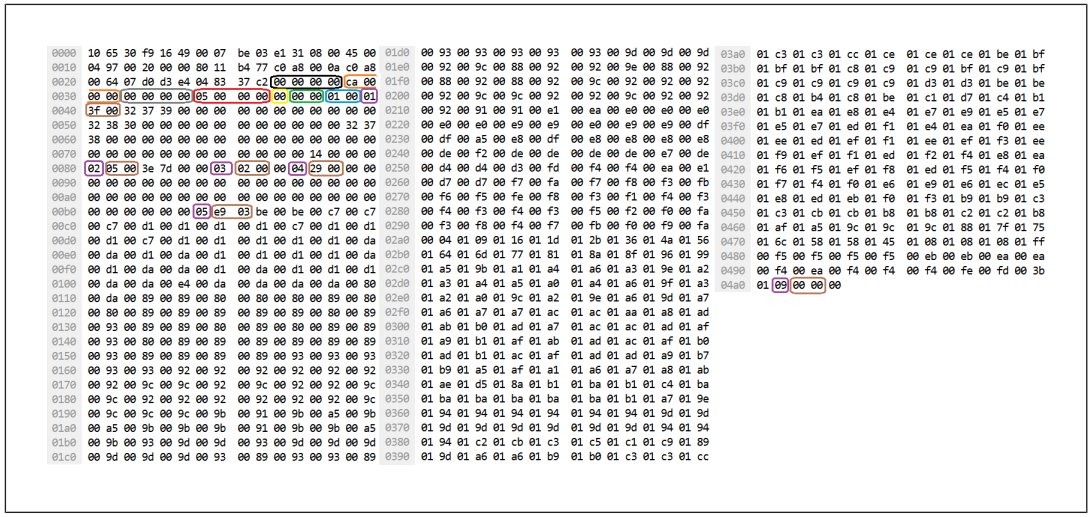


Fig.: 3 - Master frame 1

The colors used in the figure have the following meaning:

- Black: device status (format: little endian)
- Orange: operation code (format: little endian; in the example, the operation code 0xCA identifies a monitoring frame command)
- Gray: working mode
- Red: transaction type (format: little endian; in the example, the transaction type is 5)
- Yellow: scanner ID (Master is equal to zero)
- Green: from theta (start angle of this frame; format: little endian)
- Blue: resolution (format: little endian)
- Purple: header ID (see Table 1 for the list of IDs and data requested)
- Brown: payload length (+ 1) in bytes of the corresponding ID (format: little endian). In the example, this field is 0x3F = 63. This means that 63 must be added to the current position to move to the start of the next header ID.

The frame format does not change between zones, but values can. In particular, “from theta” values change according to the start angle value of the relevant frame.

In the example shown in Figure 3, the “from theta” value is as follows:

- Hex 0x0000 (decimal 0) for the first frame
- Hex 0x01F4 (decimal 500) for the second frame
- Hex 0x03E8 (decimal 1000) for the third frame
- Hex 0x05DC (decimal 1500) for the fourth frame
- Hex 0x07D0 (decimal 2000) for the fifth frame
- Hex 0x09C4 (decimal 2500) for the sixth frame

Table 1: Header and payload

HEADER VALUE	DESCRIPTION	PAYLOAD LENGTH
0x01	I/O data	0x003F
0x02	Scan counter	0x0005
0x03	Zone set	0x0002
0x04	Diagnostics	0x0029
0x05	Measures	0x039E
0x09	End of frame	0x0000

7.1.4 Monitoring frame from Subscriber device

Differently from the Master, a Subscriber device does not divide its 275° into six zones, but it can send all 275° values through a single frame (the maximum resolution it can support is 0.5 degrees, which is why a single frame for each scan is enough to send all data).

Figure 4 shows a Subscriber frame:

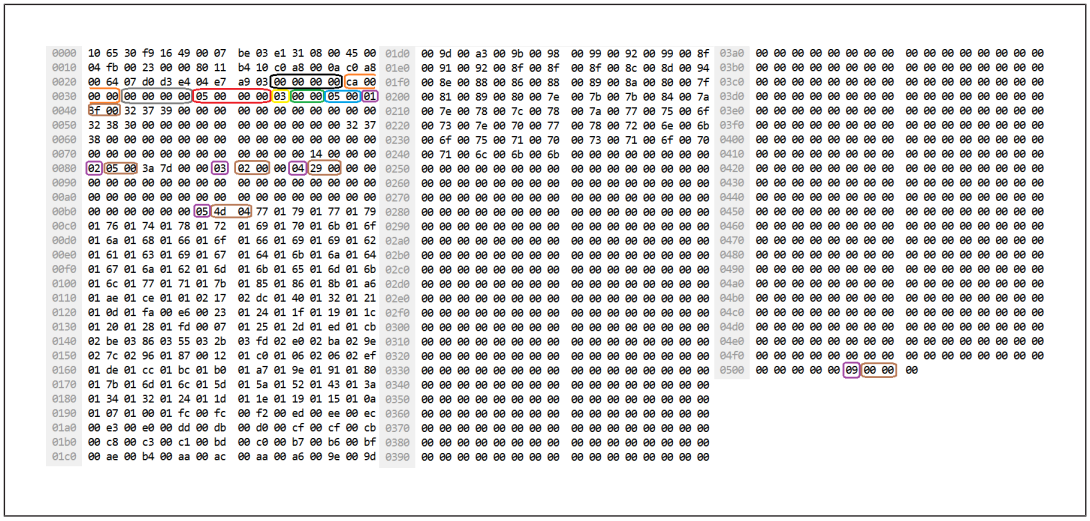


Fig.: 4 – Subscriber 3 frame

The colors used in the figure have the following meaning:

- Black: device status
- Orange: operation code
- Gray: working mode
- Red: transaction type
- Yellow: scanner ID
  - First subscriber equal to one
  - Second subscriber equal to two
  - Third subscriber equal to three
- Green: from theta (start angle of this frame)
- Blue: resolution
- Purple: header ID (the data transferred is the same as the Master device, see Table 1 Monitoring frame created by the Master device [📖 30] for the list of IDs and data requested)
- Brown: payload length of the corresponding ID

7.2 Full Angle Monitoring

7.2.1 Start request

Figure 5 shows a custom start command request:

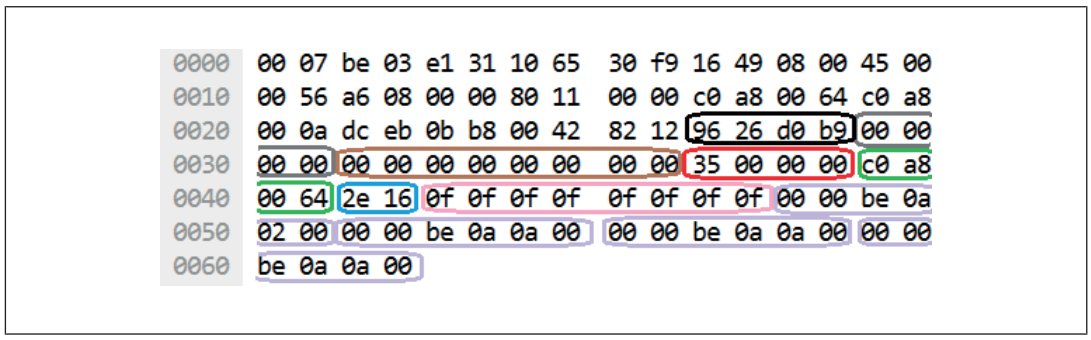


Fig.: 5 - Start request

The colors used in the figure have the following meaning:

- Black: CRC of the command
- Gray: sequence number
- Brown: reserved (empty)
- Red: operation code
- Green: IP address of the receiver client
- Blue: port number
- Pink: enabled bit (in this case all data types are enabled on four devices)
- Purple: each slot represents the start angle, stop angle, and resolution for each device. Each value is 2-byte long and expressed in tenth of degree:
  - Master (first slot): start angle is 0, stop angle is 2750, resolution is 2
  - Subscribers (second, third and fourth slots): start angle is 0, stop angle is 2750, resolution is 10

The start command response is the same as the one described in Start reply [📖 29].

7.2.2 Monitoring frame created by the Master device

Figure 6 shows the Master frame for the second zone (50 - 100°):

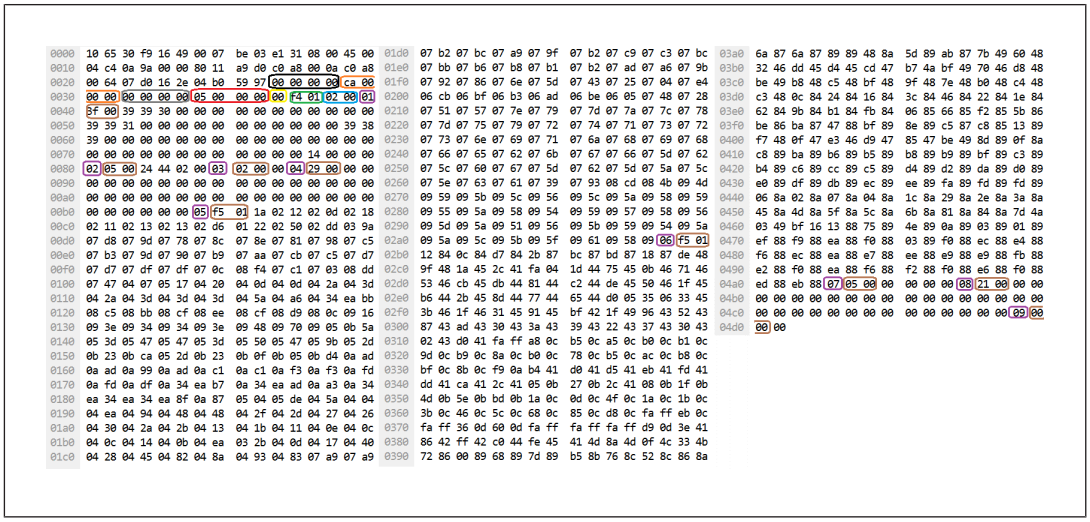


Fig.: 6 - Master frame 2

The colors used in the figure have the following meaning:

- Black: device status
- Orange: operation code
- Gray: working mode
- Red: transaction type
- Yellow: scanner ID (Master is equal to zero)
- Green: from theta (start angle of this frame, 0x1F4 equals 500)
- Blue: resolution (0x02)
- Purple: header ID (see Table 2 for the list of IDs and data requested)
- Brown: payload length of the corresponding ID

Table 2 - Header and payload

HEADER VALUE	DESCRIPTION	PAYLOAD LENGTH
0x01	I/O data	0x003F
0x02	Scan counter	0x0005
0x03	Zone set	0x0002
0x04	Diagnostics	0x0029
0x05	Measures	0x01F5
0x06	Intensity	0x01F5
0x07	Encoder	0x0005
0x08	Point in safety	0x0021
0x09	End of frame	0x0000

7.2.3 Monitoring frame from Subscriber device

Figure 7 shows the Subscriber frame:

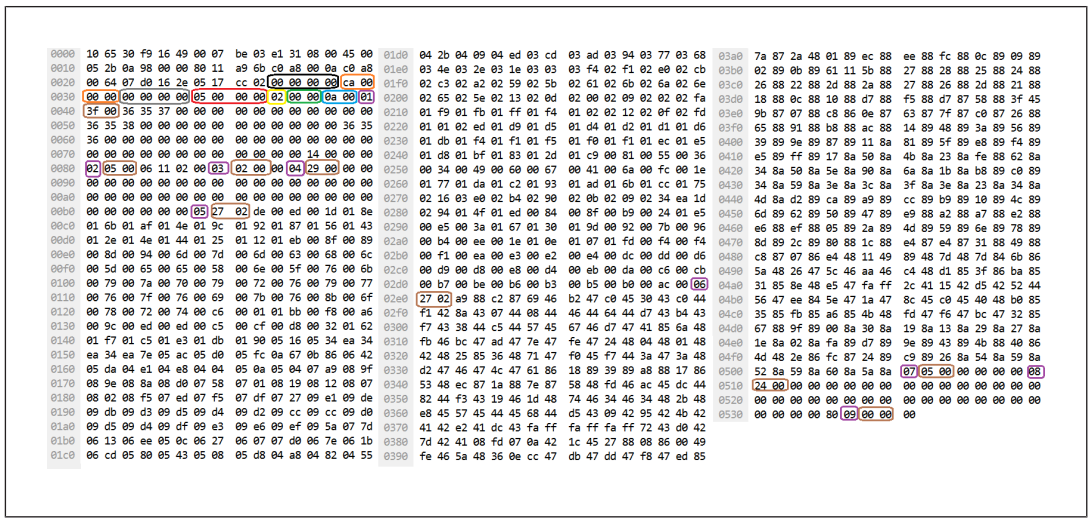


Fig.: 7 - Subscriber 3 frame

The colors used in the figure have the following meaning:

- Black: device status
- Orange: operation code
- Gray: working mode
- Red: transaction type
- Yellow: scanner ID (in this case the second Subscriber has value equal to 0x02)
- Green: from theta (start angle is equal to 0x00)
- Blue: resolution (0x0A)
- Purple: header ID (the data transferred is the same as the Master, see Table 2 Monitoring frame created by the Master device [📖 34] for the list of IDs and data requested)
- Brown: payload length of the corresponding ID

7.3 Partial Angle Monitoring

It is possible to request not only full angle data, but also partial angle data.

In this example, the monitoring data request in the range 70 - 230° will be analyzed.

7.3.1 Start request

Figure 8 shows a custom start command request:

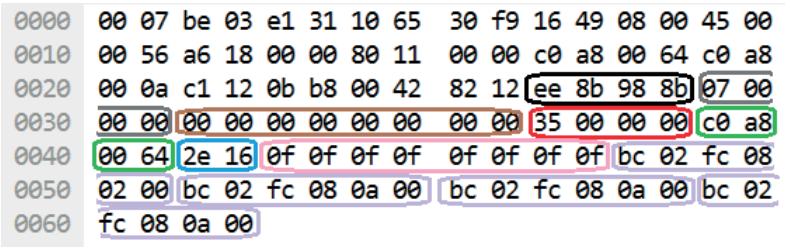


Fig.: 8 - Start request

The colors used in the figure have the following meaning:

- Black: CRC of the command
- Gray: sequence number
- Brown: reserved (empty)
- Red: operation code
- Green: IP address of the receiver client
- Blue: port number
- Pink: enabled bit (in this case all data types are enabled on four devices)
- Purple: each slot represents the start angle, stop angle, and resolution for each device. Each value is 2-byte long and expressed in tenth of degree:
  - Master (first slot): start angle is 700, stop angle is 2300, resolution is 2
  - Subscribers (second, third and fourth slots): start angle is 700, stop angle is 2300, resolution is 10

7.3.2 Monitoring frame created by Master device

In this case, the Master frame will be received as in Table 3: the first and last frames are outside the angle range requested and all header IDs are present except for the payload of measure related data (measure, intensity and point in safety), for which the header ID length is equal to one.

The second and fifth frames contain measure related data of only a part of the sector. The third and fourth frames contain measure related data of the entire sector.

Table 3: Master frame content

FRAME NUMBER	I/O PIN	SCAN COUNTER	ZONE SET	DIA-GNOSTICS	MEAS-URE	INTENS-ITY	EN-CODER	POINT IN SAFETY
1	x	x	x	x			x	
2	x	x	x	x	x	x	x	x
3	x	x	x	x	x	x	x	x
4	x	x	x	x	x	x	x	x
5	x	x	x	x	x	x	x	x
6	x	x	x	x			x	

Figure 9 and Figure 10 show the Master frame for the first (0 - 50°) and sixth (250 - 275°) frames. The behavior described above can be observed (only header ID highlighted in purple).

```
0000  10 65 30 f9 16 49 00 07  be 03 e1 31 08 00 45 00
0010  00 bc 0f fc 00 00 80 11  a8 76 c0 a8 00 0a c0 a8
0020  00 64 07 d0 16 2e 00 a8  5c 69 00 00 00 00 ca 00
0030  00 00 00 00 00 00 05 00  00 00 00 00 00 02 00 01
0040  3f 00 31 35 36 00 00 00  00 00 00 00 00 00 00 00
0050  31 35 37 00 00 00 00 00  00 00 00 00 00 00 31 35
0060  35 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
0070  00 00 00 00 00 00 00 00  00 00 00 00 14 00 00 00
0080  02 05 00 af 66 04 00 03  02 00 00 04 29 00 00 00
0090  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00a0  00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00
00b0  00 00 00 00 00 00 05 01  00 06 01 00 07 05 00 00
00c0  00 00 00 08 01 00 09 00  00 00
```

Fig.: 9 - Master frame 1

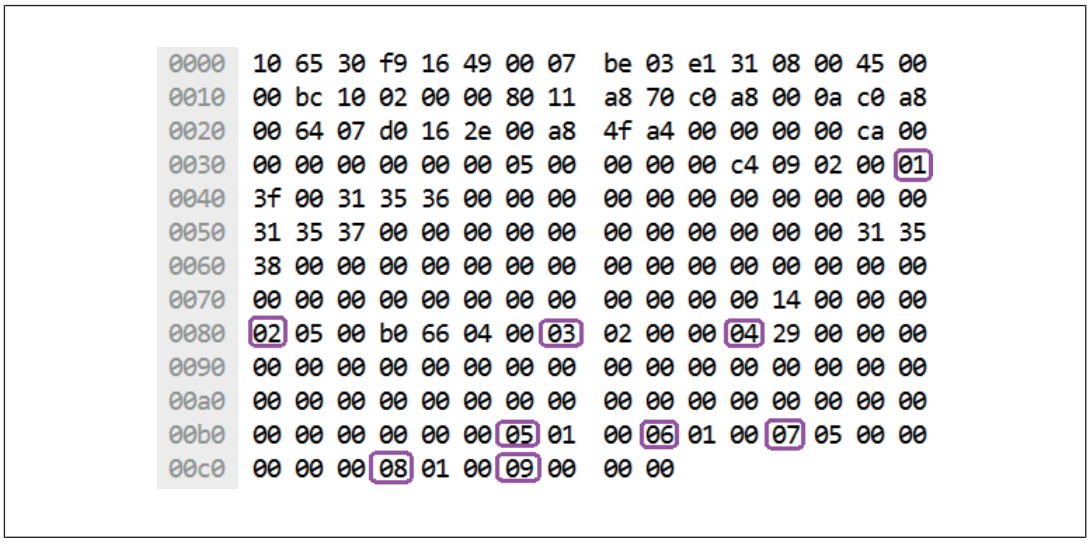


Fig.: 10 - Master frame 6

Figure 11 shows the second frame (50 - 100°), where the data requested corresponds to a part of the sector. The start angle is not 500, but 700.

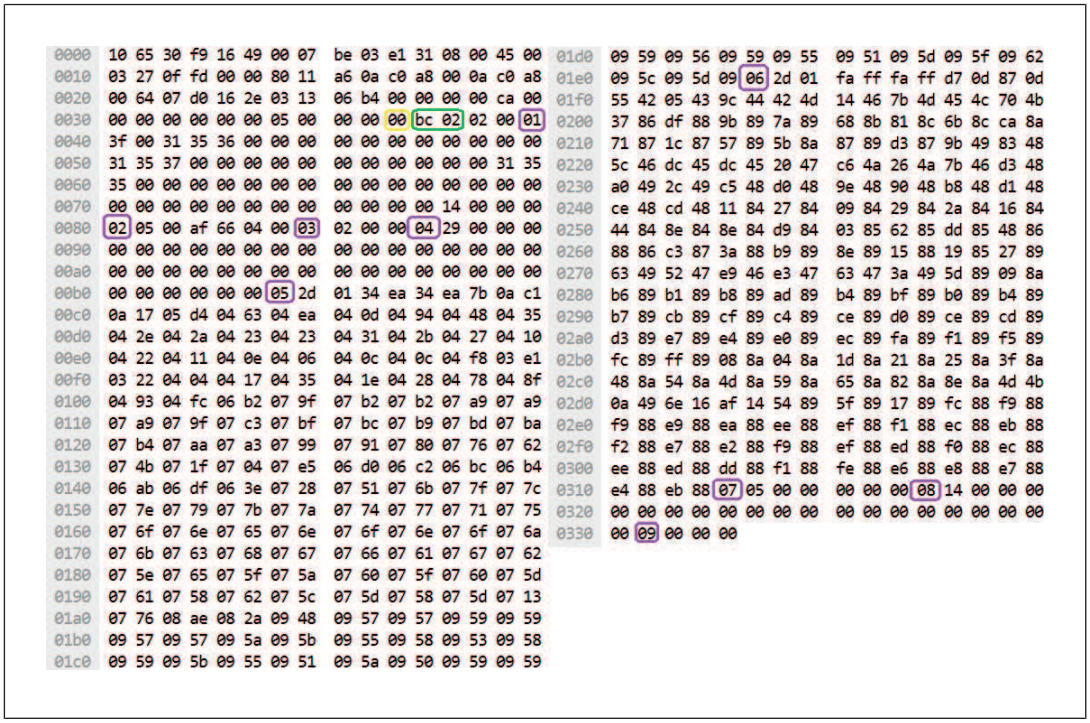


Fig.: 11 - Master frame 2

7.3.3 Monitoring frame from Subscriber device

Figure 12 shows the Subscriber 1 frame. The start angle is not zero, but 700.

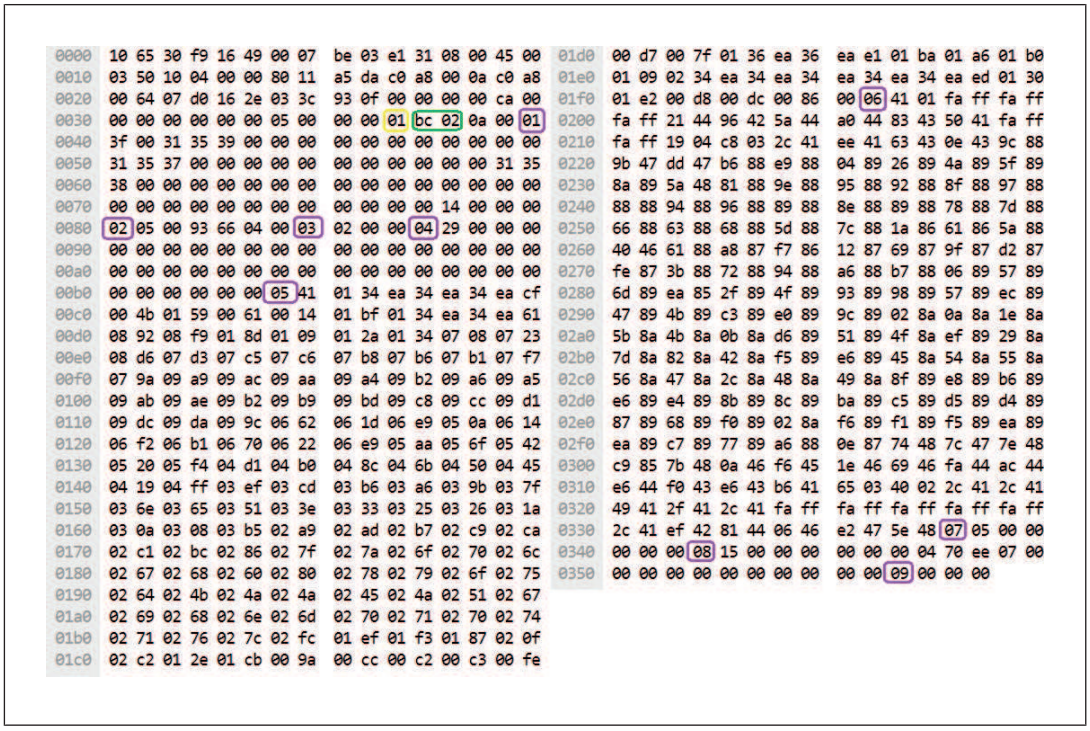


Fig.: 12 - Subscriber 1 frame

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