User Manual

2.4 GHz Radar Sensor IPS-149

Manual **IRS21**

Version V1.29C (09/2006)

Lufft

Table of contents

1 GENERAL REMARKS 4

2 STORAGE CONDITIONS 5

3 OPERATING CONDITIONS 5

4 APPROVALS 5

5 QUALITY 5

6 SYSTEM DESCRIPTION 6

6.1 HARDWARE 6

6.2 THE INTERFACES 8

7 MOUNTING AND INSTALLATION 10

7.1 PREPARATION 10

7.2 MOUNTING 11

7.3 CONNECTION OF THE SUPPLY LEAD 12

7.4 COMMISSIONING AND TESTING 14

8 MAINTENANCE 14

8.1 EXCHANGE OF THE SENSOR 14

9 IRS-21 PROTOCOL 16

9.1 INTRODUCTION 16
9.1.1 IRS-21 BUS PROTOCOLS 16
9.2 BINARY PROTOCOL 17
9.2.1 TELEGRAM SETUP (DESCENDING BYTE SERIES) 17
9.2.2 PHYSICAL CONDITIONS 17
9.2.3 COMMANDS 18
9.2.4 DEFINING THE IDENTIFICATION 22
9.3 ASCII-PROTOKOLL (IRS-21 <-> HOST COMPUTER) 23
9.3.1 PHYSICAL CONDITIONS AND FEATURES 23
9.3.2 COMMANDS FOR READING OUT MEASUREMENT VALUES 24
9.3.3 EEPROM CONFIGURATION + ADDRESSING THE RS485 BUS 27
9.4 BINARY PROTOCOL (IRS-21 OVER OPUS200/300 <-> HOST COMPUTER) 28
9.4.1 PHYSICAL CONNECTION AND HARDWARE STRUCTURE 28
9.4.2 SOFTWARE PROTOCOL 28
9.4.3 TELEGRAM AND DATA FORMAT 29
9.4.4 CONFIGURATION OF THE OPUS200 MODULES 32
9.4.5 CONFIGURATION OF THE ROAD SENSOR 33
ENCLOSURE 35

10 COMPLIANCE STATEMENT 36

1 General remarks

The IRS-20/21 Road Sensor serves to monitor road conditions.
In contrast to most other sensors on the market, the IRS determines the road condition within the sensor itself. This was made possible by means of a high-end microcontroller and a sensor system which consists of the following components:

- Surface temperature measurement.
  Two additional temperature sensors can be connected for measuring temperature under ground. These latter values are not taken into account for determining the road condition.
- Multi-frequency measurement
- Measurement of salt concentration and freezing temperature
- Determination of the water film height on the surface of the sensor.

Depending on the measured values the IRS-20/21-software calculates a possible road condition based on correlation factors and operates within a temperature range from –20°C to +60°C.
For temperature values higher than a nominated temperature TPOS (default value 2ºC) the model recognises the conditions "Dry", "Residual Salt", "Damp" and "Wet". Values below TPOS additionally allow the determination of "Freezing Wetness", "Hoar Frost / Dry Snow" and "Ice / Wet Snow".
The IRS-20 can be used only in combination with a Lufft datalogger OPUS 2.
The IRS-21 can be connected to any host computer which is able to support one of the communication protocols described in chapter 9.

Furthermore, the sensor has the following characteristics:

- Compact construction and easy installation
- Low maintenance
- Resistant to physical and chemical influences
- Exchangeable even when installed
- Data transmission via RS 485 (IRS-21)
- Measurement time < 2s, therefore low energy consumption

2 Storage conditions

Permissible ambient temperature ....-30°C ... +70°C

Permissible relative humidity ....0...100 % rel. humidity

3 Operating Conditions

Permissible ambient temperature ....-30°C ... +70°C

Permissible relative humidity ....0...100 % rel. humidity

Protection Class..IP68

4 Approvals

Design conforms to CE

5 Quality

Warranty period ....2 years

Maintenance interval...annually

6 System description

6.1 Hardware

The sensor consists basically of two components:

- Basic housing with connection cables for communication and power supply
- Housing cover with sensor electronics and evaluation electronics

These two components are joined together by 6 screws.
Two concentric circles on the sensor surface provide the measurement values for the multi-frequency measurement. Alonside, in a recess, there are two electrodes that provide information about salt concentration and thereby the freezing temperature. Additionally, a temperature sensor, which determines the surface temperature, is installed in the central electrode.
Beneath the remainder of the surface is the aerial for the impedance sensor, by means of which the water film height above the cover can be determinded.
The printed circuit board, which contains the signal conditioning and evaluation electronics, is also directly connected to the cover. Data is output via an RS485 interface.

Important!!
Power consumption during measurement is approximately 200 mA. In order to exclude measurement errors through self-heating, the IRS-20/21 should only be supplied with power only for approx. 2s.
For the IRS-20 this is controlled by the OPUS2.
The IRS-21 **must** be switched on and off by the control program of the host system.

After data interrogation, therefore, the sensor must be free of voltage. The measurement interval must be >1 minute.

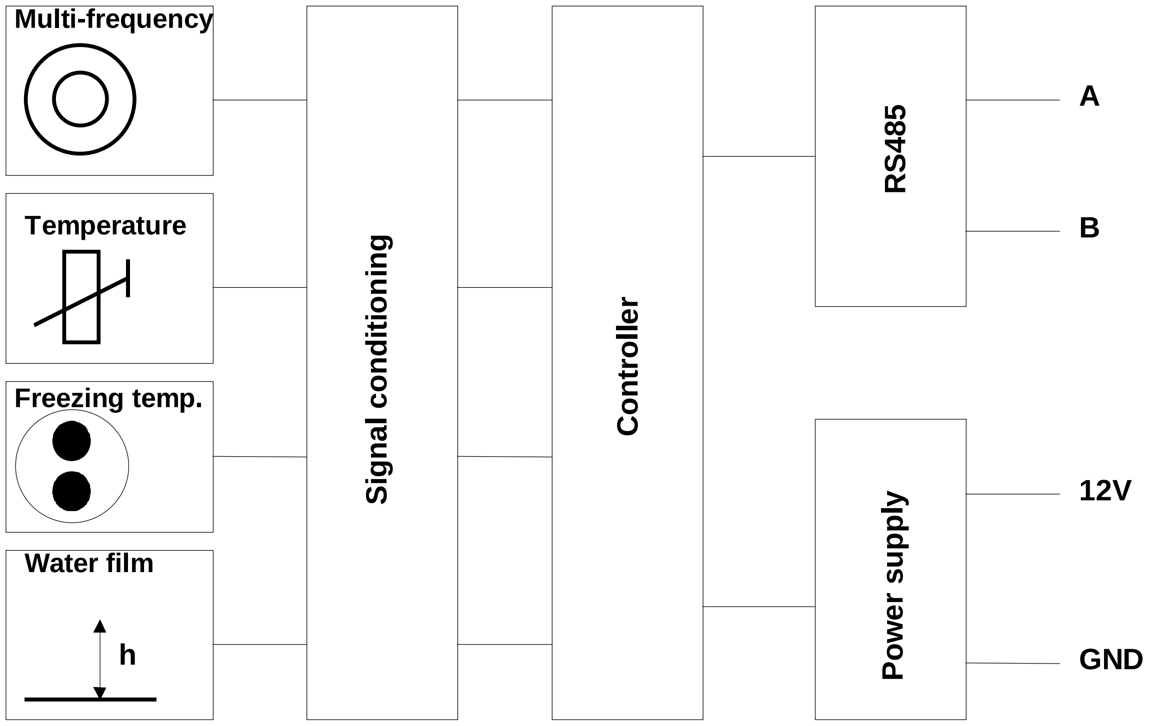


Illustration 1: IRS-20/21 Schematic Unit Diagram

6.2 The Interfaces

Illustration 2 shows three possible combinations by means of which the IRS-20/21 can communicate with terminal devices. Please also consider the manual 8410.KON2.

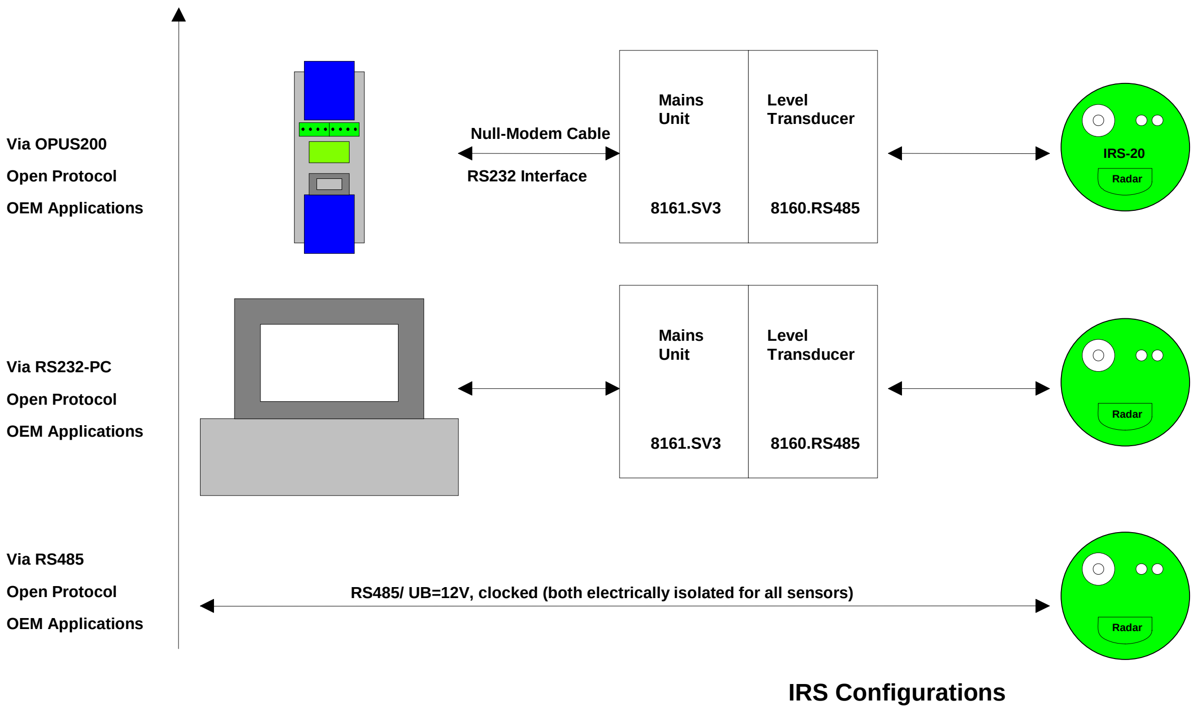


Illustration 2: IRS-20/21 Connection Possibilities

The combination IRS-20 and OPUS200 is useful when, in addition to the IRS-20 data, additional measurement values are to be distributed via a common interface. Interrogation takes place via the RS232 interface of the OPUS200/300.

The combination IRS-20 and PC (RS232 terminal device) can be applied when the terminal device has an RS232 interface. The modem control lines can be used in combinations with an appropriate program for switching the data direction (from the host computer to the IRS-21 and/or from IRS-21 to the host computer) as well as the power supply of the IRS-21. Concerning the hardware, this function is provided by the combination mains unit (8161.SV3) and level transducer (8410.KON2). The terminal device software is responsible that power is not supplied longer than it is necessary for the data transmission. The measurement interval must be >=1 minute.

The same conditions apply when the sensor is read out directly via the RS485 interface.

When using the level transducer (8410.KON2) the following aspects must be taken into account in the control software of the host computer (PC):

- The modem control line 'DTR' (Pin 4 of a 9 pin RS232 cable) switches the IRS power supply 'on' (H level [approx. +10 V]) or 'off' (L level [approx. -10 V]), respectively. The current state can be seen on a red LED on the circuit board of the level transducer.
- The modem control line 'RTS' (Pin 7 of a 9 pin RS232 cable) controls the data direction (halfduplex) from the host computer to the IRS (L level [approx. -10V]) or from the IRS to the host computer (H level [approx. +10V]), respectively.
- The IRS is always the slave. That means, the communication is always initiated by the host program.
- Before starting the communication, the IRS power supply has to be switched on for about 2 seconds, so that the sensor can carry out measurements. Commands which the host system sends too early will be ignored by the IRS.
- Immediately after transmitting the command telegram, the host computer **must** switch the data direction of the level transducer to 'IRS to host' by using the 'RTS' control line.
- The level transducer will instantaneously return all characters sent by the host (echo). These should be ignored by the control software.
- The IRS will wait about 100ms before answering.
- After reception of the IRS answer the data direction should be switched back to 'host to IRS' and the power supply for the road sensor should be deactivated.

The protocols for data transmission can be found from chapter 9 onward.

7 Mounting and Installation

The road sensor is installed in the centre of the road lane. On two lane carriageways installation takes place in the left-hand lane.

7.1 Preparation

For inserting the sensor you need a drill hole with a diameter of 16 cm and a depth of 6 cm. For the connection cable mill-cut a slot of width 2cm and depth 5cm into the road surface.

Attention! Be careful not to damage the isolation layer when working on bridges. A depth of 6cm may not be possible in any case.

The installation of temperature sensor 1 (optional) requires an additional slot in an angle of about 68º from the connection cable slot. The temperature sensor slot will be mill-cut into the road with a width of 2 cm, depth 5 cm and length 35 cm.

For temperature sensor 2 (optional) a drill hole of 30cm depth with diameter 2cm is required. This is supposed to be positioned in an angle of about –68º on the outer rim of the road sensor bore hole.

The external temperature sensors are protected to IP67. Constant use under water has to be avoided.

7.2 Mounting

Warning: The cable unions must no be opened in any case!

Shortening the cable is only permitted at the cabinet end of the cable. The cable must be placed in a protection tube which prevents pavement expansions from being transmitted to the cable. Be careful not to expose the sensor cables to tensile stress during the installation!

Warning: Damages on the cable sheathing or on the external temperature sensors will lead to water entering the sensor! Sensors with damaged cabled must not be built in and can only repaired by Lufft.

The road sensor is inserted into the corresponding drill hole so that its surface flushes with the pavement. In order to achieve this, put the mounting bracket which is fixed on the sensor on the rim of the drilling hole. If necessary, adjust the sensor position by bending the mounting bracket.

Important:
The road sensor must by no means jut out over the pavement surface (Possible damages through snow clearing vehicles!).

Hollow spaces will be filled with resine concrete.

Important: Reaction heat in the resine concrete curing process can sometimes reach temperatures over 80 °C (176ºF) which will damage the road sensor. It is important to use only materials whose temperature remains below 80 °C (176ºF) in the curing process!

When the filling compound is hardened, remove the mounting bracket and the green plastic protection layer. The screws of the mounting bracket must be re-inserted in the corresponding screw holes of the road sensor (turning moment 2 Nm).

7.3 Connection of the Supply Lead

The road sensor supply lead is connected with the power supply and the bus system of the evaluation electronics in the control panel.

Connection of the road sensor supply lead:

brown	positive power supply
white	negative power supply
yellow	RS485_A
green	RS485_B

Attention: Errors in connection will destroy the road sensor!

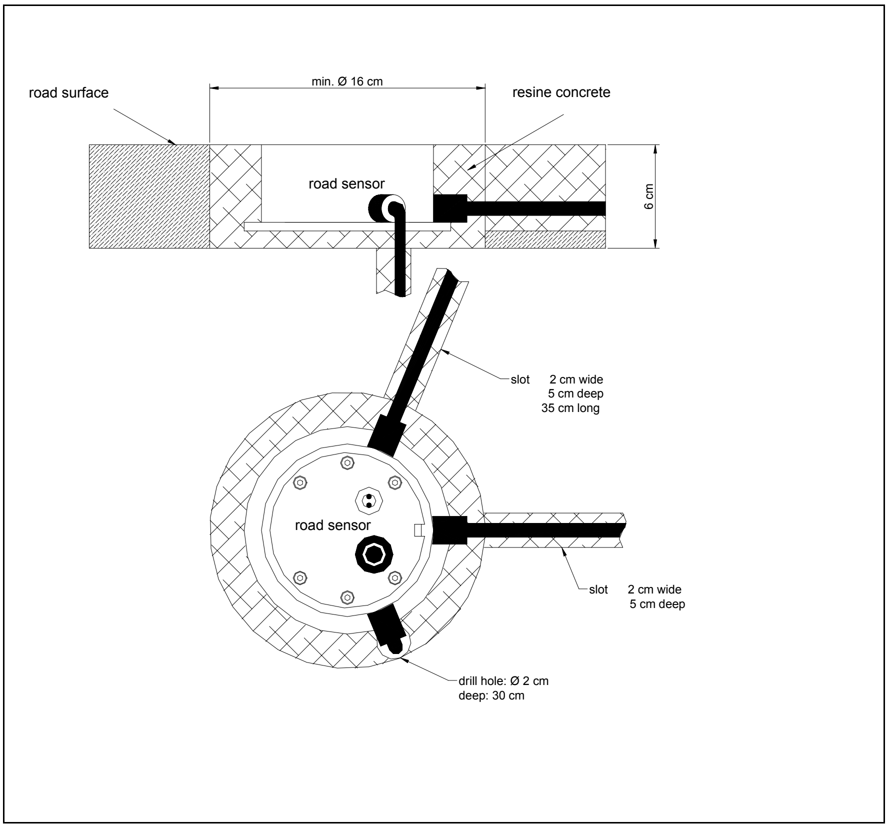


Illustration. 3: IRS20/21 Installation in the road

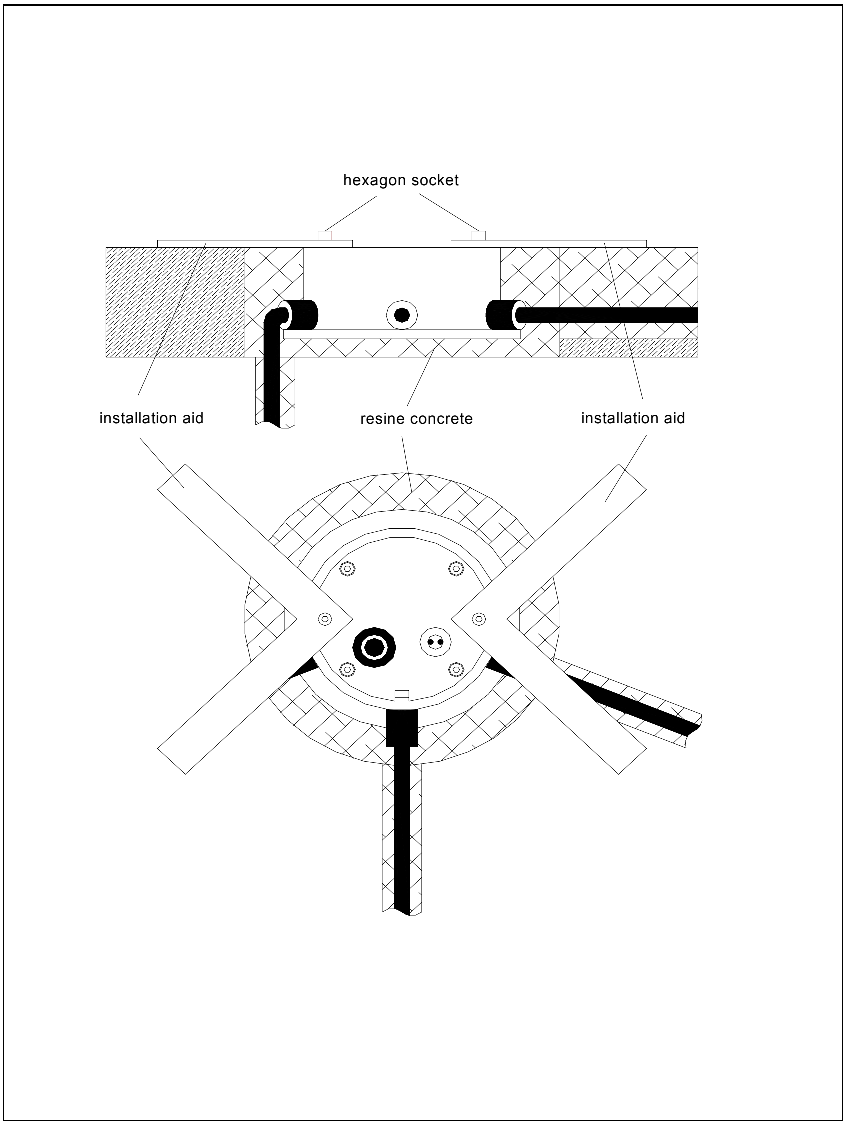


Illustration 4: Mounting the IRS20/21

7.4 Commissioning and Testing

After successful installation of the road sensor, its correct functioning should be checked.

Connect the sensor to your evaluation device and check whether the communication between the sensor and the evaluation unit works properly. The road condition which is determined by the sensor should be checked for dry **and** wet sensor.

8 Maintenance

The road sensor should be serviced annually. This includes the visual inspection of the housing. It is recommended to clean the sensor surface when very dirty. Where there is significant mechanical damage to the sensor, which could influence the tightness of the housing, it is recommended to exchange the sensor. This also applies in the case where the plastic assembly of the sensor is heavily degraded by wear and tear.

8.1 Exchange of the sensor

If the plastic assembly of the road sensor becomes unusable due to mechanical effects, or the sensor electronics are damaged, the plastic assembly can be exchanged without the need to exchange the entire housing.

Attention:
Exchange must only be carried out when the road is dry!

To uninstall the plastic assembly remove all six hexagonal screws. On the edge of the cover there is a small opening that serves to provide access for a screwdriver. Thereby the plastic assembly can be lifted out. Take care not to pull out the connection cables on the underside of the sensor. The plug connections must be removed without tensile strain on the cables!

Important:
when changing the sensor the ring gasket must always be replaced and a new drying agent bag must be laid in!

The housing has to be cleansed carefully before inserting a new sensor. Even tiny dirt particles in the gasket fit may lead to sensor failure in the long term! No humidity must be enclosed in the housing! The new drying agent bag must be taken out of the sealed protection cover only shortly before being placed in the housing. The sticker on its outside indicates the functioning (blue: ok, pink: the drying agent is spent).

When connecting the new sensor to the plugs be careful not to touch the electronics of the sensor. Electrostatic discharge may easily destroy the sensor!

The gasket has to be placed using silicone grease. It must not cant when the plastic cover plate is inserted. The plastic cover plate must fit into the housing without the use of force. Grease the thread of the fixing screws. First lightly fasten the screws and then tighten them one by one proceeding in pairs of screws placed opposite each other.

9 IRS-21 Protocol

9.1 Introduction

Both types of intelligent road sensors are equipped with 2 different types of interfaces for the communication with superordinate systems:

- IRS-20: Only for use with the Lufft datalogger OPUS-2.
  (The protocol of this interface is not included in this manual)
- IRS-21: Flexible connection of several road sensors via one RS485 interface
  (2 wire, half duplex) to a customer designed host computer

9.1.1 IRS-21 bus protocols

The IRS-21 provides for 2 different communication protocols in order to grant easy connectivity to a superordinate host system:

- Binary protocol (Chapter 10.2)
  Data frame limited by the control characters STX (02h) and ETX (03h)
  CRC (cyclic redundancy check)
- ASCII protocol (Chapter 10.3)
  Plain text protocol with end characters CR (0Dh) + LF (0Ah)

Both types can be used on a bus, i.e. every road sensor can have its own address and be connected to a host computer.

9.2 Binary protocol

The binary protocol is used for connecting host computer (e.g. OPUS200) to the Intelligent Road Sensor via RS485:

9.2.1 Telegram setup (descending byte series)

Byte number	**Meaning**	**Abbr**	**Range**
1	Telegram start	STX	0x02
2	Identicifacation	ID	0 ... 250
3	Length	CNT	1 ... 255
4	Command	CMD	0 ... 255
5 ... n	Additional data	D0 ... Dn	0 ... 254 Bytes
n + 1 n + 2	Block check	CRC_L CRC_H	16 Bit CRC check sum from ID until the last Data byte
n + 3	End of telegram	ETX	0x03

9.2.2 Physical conditions

Interface: RS485 – 2 wire (half duplex)

Data bits: 8

Stop bits: 1

Parity: none

Baudrate: 19200 Baud (Default setting)
(1200 Bd., 2400 Bd., 4800 Bd., 9600 Bd., 19200 Bd., 38400 Bd. can be adjusted)

Check sum: 16 Bit CRC from Ident.-Byte (ID) until the last data byte
CRC polynomial: $x^{16} + x^{12} + x^5 + 1$ (LSB first mode); see enclosure

Timeout: Answer from the slave must be available max. 0.5 Sec. after request from the master

Ident: On delivery = 0

9.2.3 Commands

9.2.3.1 Request of data from IRS21 to host

Sensor is connected (CMD = 0x00)

Host: STX, ID, CNT = 2, CMD = 0x00, D0, CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 2, CMD = 0x00, inverted D0 value, CRC_L, CRC_H, ETX

Example: Master sends D0 = 0x55, IRS-21 answers D0 = 0xAA

Request of soft and hardware version (CMD = 0x01)

Host: STX, ID, CNT = 1, CMD = 0x01, CRC_L = 0x51, CRC_H = 0x08, ETX

IRS-21: STX, ID, CNT = 3, CMD = 0x01, D0 = HW, D1 = SW , CRC_L, CRC_H, ETX

Example: HW = 04 -> hardware version 0.4; SW = 23 -> software version 2.3

Request of individual sensor data (CMD = 0x02)

Host: STX, ID, CNT = 2, CMD = 0x02, D0 = Sensor (see table), CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 3, CMD = 0x02, D0 = Lowbyte (see table), D1 = Highbyte (see table below), CRC_L, CRC_H, ETX

Host D0 = Sensor	Sensor type	Range	**IRS-21** D0 = Low- / D1 = Highbyte
0	Internal temperature sensor	0 ... 2000 Digits = -50,0 °C ... +150,0 °C.	0 ... 2000 in case of error 50000
1	External temperature sensor - 1	0 ... 2000 Digits = -50,0 °C ... +150,0 °C.	0 ... 2000 in case of error 50000
2	External temperature sensor - 2	0 ... 2000 Digits = -50,0 °C ... +150,0 °C.	0 ... 2000 in case of error 50000
3	Multi frequency – 1000k	0 ... 255 Digits	0 ... 255 / 0

4	Multi frequency – 500k	0 ... 255 Digits	0 ... 255 / 0
5	Multi frequency – 200k	0 ... 255 Digits	0 ... 255 / 0
6	Multi frequency – 51k	0 ... 255 Digits	0 ... 255 / 0
7	Salt concentration Freezing temperature	0 ... 250 Digits = 0,0 % ... 25, 0% (NaCl) 0 ... 250 Digits = 0,0 °C ... -25.0 °C.	Lowbyte: 0 ... 255 Highbyte: 0 ... 255
8	Impedance sensor	0 ... 250 Digits = Normalised value 0...255 Digits = Humidity adaptation	Lowbyte: 0 ... 250 Highbyte: 0 ... 255
9	Water film height	0 ... 4000 Digits = 0 ... 4000 µm	0 ... 4000

Request of sensor data for being stored in the host as a block (CMD = 0x03) (CMD = 0x03)

Host: STX, ID, CNT = 1, CMD = 0x03, CRC_L = 0x43, CRC_H = 0x2B, ETX

IRS-21: STX, ID, CNT = x, CMD = 0x03, D0 ... D13 (see table below), CRC_L, CRC_H, ETX

IRS-21 D0 ... D11	Meaning
0 / 1	Internal temp. sensor (0 ... 2000 Digits = -50,0 °C ... +150,0 °C.) (Byte 0 = Lowbyte, Byte 1 = Highbyte)
2 / 3	Externeral temp. sensor - 1 (0 ... 2000 Digits = -50,0 °C ... +150,0 °C.) (Byte 2 = Lowbyte, Byte 3 = Highbyte)

4 / 5	External temperature sensor – 2 (0 ... 2000 Digits) (Byte 4 = Lowbyte, Byte 5 = Highbyte)
6 / 7	Byte 6 = Freezing temperatures (0 ... 250 Digits) Byte 7 = 0
8 / 9	Byte 8 = Normalised radar value (0 ... 250 Digits) Byte 9 = 0
10 / 11	Water film height (0 … 4000 Digits = 0 ... 4000 µm) (Byte 10 = Lowbyte, Byte 11 = Highbyte)
12 / 13	Byte 12 = Defined Road Condition (0 ... 99) 0: Dry 1: Damp 2: Wet 3: Ice 4: Frost/Snow 5: Residual salt 6: Freezing wet > 6: Undefined condition Byte 13 = Physical Road Conditions (0 ... 99) 0: Dry 1: Residual salt 2: Damp 3: Wet 4: Freezing wet 5: Hoarfrost 6: Dry snow 7: Dry ice 8: Wet snow 9: Ice > 9: Undefined condition The defined road condition is a subset of the physical road condition.

Read out individual EEPROM memory cells (CMD = 0x04)

Host: STX, ID, CNT = 3, CMD = 0x04, D0 = Lowbyte address, D1 = Highbyte address, CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 5, CMD = 0x04, D0 = Lowbyte address, D1 = Highbyte adres-se

, D2 = Lowbyte date, D3 = Highbyte date, CRC_L, CRC_H, ETX

Note: The EEPROM address range is 0 ... 2047.

Read out EEPROM memory cells as block (CMD = 0x05)

Host: STX, ID, CNT = 4, CMD = 0x05, D0 = Lowbyte start address, D1 = Highbyte Start address, number of words, CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 3 + 2 x number of words, CMD = 0x05, D0 = Lowbyte start ad-dress,

D1 = Highbyte start address, D2 = Lowbyte date, D3 = Highbyte date,

D4 = Lowbyte date, ..., Dn = Highbyte date, CRC_L, CRC_H, ETX

Note: The number of words is limited to 32 (= 64 Byte).

9.2.3.2 Transmission of data from host to IRS-21

Write individual EEPROM memory cells (CMD = 0x10)

Host: STX, ID, CNT = 5, CMD = 0x10, D0 = Lowbyte address, D1 = Highbyte adress, D2 = Lowbyte date, D3 = Highbyte date, CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 1, ACK = 0x06 = OK or NACK = 0x15 = error, CRC_L, CRC_H, ETX

Disable ASCII protocol (CMD = 0x11)

Host: STX, ID, CNT = 1, CMD = 0x11, CRC_L = 0xD0, CRC_H = 0x18, ETX

IRS21: STX, ID, CNT = 1, ACK = 0x06 = OK, CRC_L, CRC_H, ETX

Enable ASCII protocol (CMD = 0x12)

Host: STX, ID, CNT = 1, CMD = 0x12, CRC_L = 0x4B, CRC_H = 0x2A, ETX

IRS21: STX, ID, CNT = 1, ACK = 0x06 = OK, CRC_L, CRC_H, ETX

RESET - IRS-21 (CMD = 0x1F)

Host: STX, ID, CNT = 1, CMD = 0x1F, CRC_L = 0xAE, CRC_H = 0xF1, ETX

IRS-21: STX, ID, CNT = 1, ACK = 0x06 = OK, CRC_L, CRC_H, ETX

Note: After transmitting 'OK' the sensor is re-set.

9.2.3.3 IRS-21 answer in case of receiving wrong data from the host

IRS-21: STX, ID, CNT = 1, NACK = 0x15 = Not Acknowledged (Data were not accepted), CRC_L, CRC_H, ETX

9.2.4 Defining the identification

2 scenarios are possible:

- Establishing a new bus line
- Connecting an additional sensor to an existing bus line
  The default identification [short ID] (=0) should have been changed previously. By using ID=0 all sensors in a bus line are contacted.

Important!

It is important to make sure that the new sensor has a different ID from the sensors which are already in the line. As discussed above the new ID should be >0. The possible range is 0…250.

The command for transferring the new identification is basically the same as the one for writing EEPROM cells:

Host: STX, ID, CNT = 5, CMD = 0x10, D0 = 0x05, D1 = 0x00, D2 = new ID, D3 = 0x00, CRC_L, CRC_H, ETX

IRS-21: STX, ID, CNT = 1, ACK = 0x06 = OK or NACK = 0x15 = error, CRC_L, CRC_H, ETX

In order to have the sensor accept the new ID it has to be re-started with the reset command (with the old identification still) or by switching it off and on again.

9.3 ASCII-Protokoll (IRS-21 <-> host computer)

In addition to the above binary protocol measured values can be requested in plain text from the IRS-21. To this end, a terminal software is needed which converts incoming and outgoing data from COM ports to RS485 – 2 wire bus (halfduplex).

9.3.1 Physical conditions and features

Parameter	Options on request	Default settings
Baudrate	2400 - 38400 Baud	19200 Baud
Data bits	8 (fix)	8
Stop bits	1 (fix)	1

Interface settings for the ASCII protocol

The following features have to be taken into account:

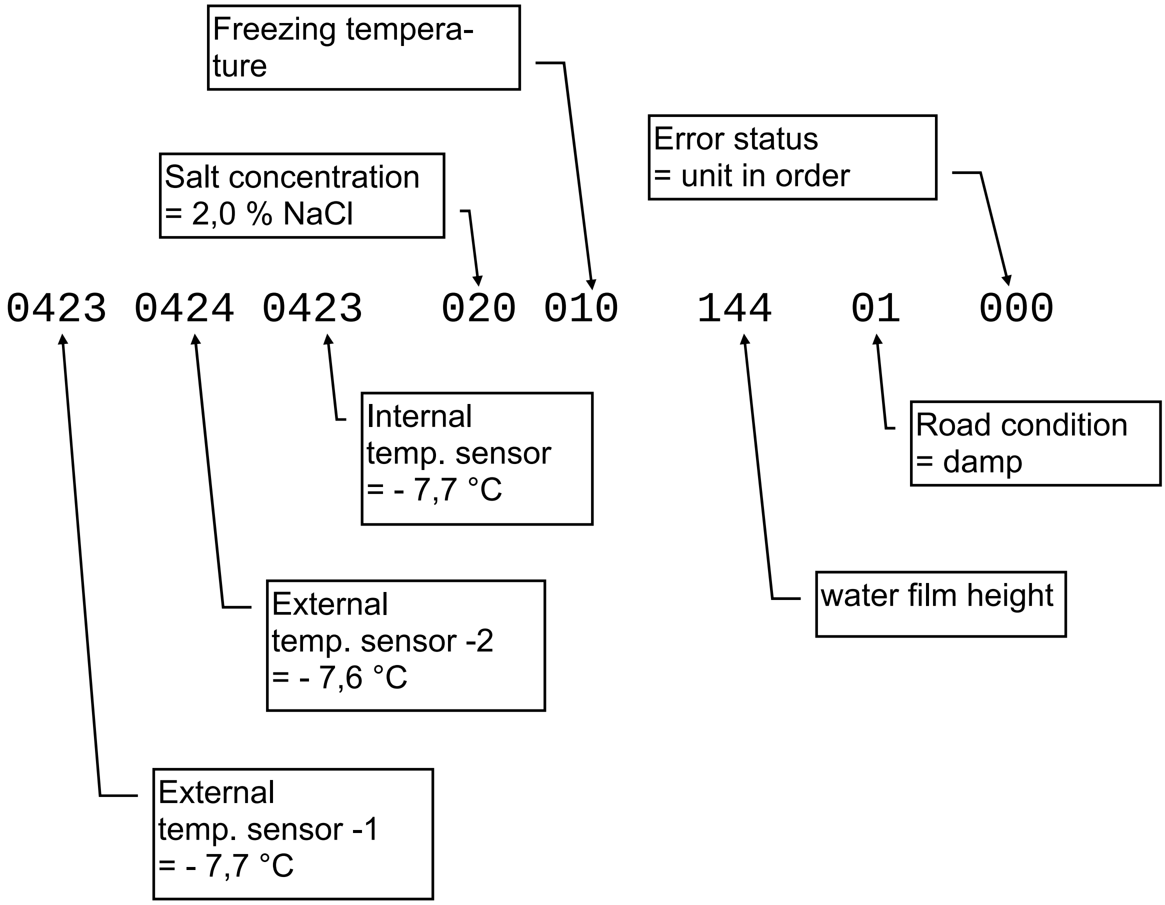
- Any command of the Host must be preceeded by '&' or '$'
- Any telegram from the host to the IRS-21 is ended by ‘CR’ (= 0Dh). All further characters will be ignored.
- Answers from the IRS to the host are always ended by ‘CR & LF’ (= 0Dh & 0Ah).
- If several values IRS->Host are trasmitted (e.g. the values of 3 temperature sensors), these will be seperated from one another by 1 'Space' (=20h). Groups of measuring values (e.g. water film and road condition) are separated from one another by 3 'Spaces'.
- In case of errors (e.g. wrong E2 memory cell) the IRS sends ‚NACK’ + ‚CR’ + ‚LF’
- For data handover the indicated digits may be reduced
  (e.g. read address 24 of the EEPROM: command EL0024 + ‚CR’ or EL24 + ‚CR’).

9.3.2 Commands for reading out measurement values

Command	Function
&T +'CR'	Output of the normalised values of 3 temperature sensors: 1st Value = External Sensor-1 2nd Value = External Sensor-2 3rd Value = Internal Sensor The respective value range covers 0 ... 2000 Digits = -50,0 ° ... +150,0 °C. For a non-connected or defective sensor the value is always 'xxx'.
&F +'CR'	Output of the normalised values of 4 frequencies of the multi-frequency measurement: 1st Value = F1000k range 2nd Value = F500k range 3rd Value = F200k range 4th Value = F51k range The respective value range covers 0...255 digits. In case of a dry or wet but clean road, the values tends towards 255. On the other hand, this value comes near '000' when the road is wet and dirty. For non-tuned or faulty frequency measurement the values are always set at 'xxx'.
&L +'CR'	Output of the normalised conductivity measurement values 1st Value = Concentration of the salt solution 0 ... 250 Digits = 0,0 % ... 25, 0% (NaCl) 2nd Value = Freezing temperature of the salt solution 0...50 Digits = 0,0 ... -25.0°C. In case the measurement cannot be determined, both values are set to 'xxx'. The measuring range for determining the salt concentrations is –20 °C... + 15 °C (internal temperature sensor).
&R +'CR'	Output of the normalised water film height in 0 ... 250 digits. On a dry road the water film value tends towards 150 (=dry). With increasing water level the value declines towards '000'. For non-tuned water film measurement the value is always set to 'xxx'.The water film can be measured up to +60°C air temperature.

&Z +'CR'	Output of the road conditions in figures 0...99: 0 = Dry 1 = Damp 2 = Wet 3 = Icy 4 = Frost / Snow 5 = Residual Salt 6 = Freezing Wet 98, 99 = undefined values (road conditions could not be determined). Road condition 99 is displayed when measuring below –20 °C and above +60 °C.
&A +'CR'	Output of all the above values in order T, L, R, Z. There are always 3 'spaces' (=20h) between the different measurement groups (e.g. 'T' and 'F'). Furthermore, the error state of the sensor is transmitted at the end of the line. The following error conditions have been defined: '000' = The unit is in order. '001' = The external temperature sensors are not connected or faulty > '001' = The unit is faulty
&V +'CR'	Output of the hard and software version. e.g. 0.4 (= HW Version) 2.0 (= SW Version) 16.06.00 (SW creation date)

Example of data output after the command &A↵ has been sent by the host computer (standard output)



9.3.3 EEPROM configuration + addressing the RS485 Bus

Command + Data	Function
&ELxxxx + 'CR'	Read EEPROM memory cell with address xxxx Address = 0 ... 2047, displayed value = 0 ... 65535 (2 Byte) Answer: yyyyy (= E2 contents) + ,CR' + ,LF'
&Essxxxx yyyyy + 'CR'	Write EEPROM on address xxxx with value yyyyy Address=0 ... 2047, Value=0 ... 65535 Answer: yyyyy (= E2 contents written and re-read) + ,CR' + ,LF'.
$ + 'CR'	Read RS485 bus ident (address) and bus selector Answer: xxx (= Ident) + 3 Spaces + yyy (= Selector) + ,CR' + ,LF'.
$Ixxx + 'CR'	Assign RS485 bus ident (address) and configuration of the bus selector to this address. Ident-No.= 1 ... 255 Answer: xxx (= Ident) + 3 Spaces + yyy (= Selektor) + ,CR' + ,LF'.
$Sxxx + 'CR'	Set new RS485 bus selector (=selection of an IRS) Selektor No = 0 ... 255 Answer: xxx (= Ident) + 3 Spaces + yyy (= Selektor) + ,CR' + ,LF'.

Addressing the IRS bus is possible only from sw version 2.2 onwards.

Remarks about the RS485 bus ident and selector:

The bus ident corresponds to the bus address in the binary protocol.

The bus selector is used for selecting a determined IRS. All other participants on the bus will remain passive until a new selector no. is set. A new ident no. can only be assigned to a selected IRS.

The selector no. is set to the new value at the same time as the new ident no. The IRS remains therefore selected in spite of the changed ID. Every participant in the bus **must** have its own ident no.

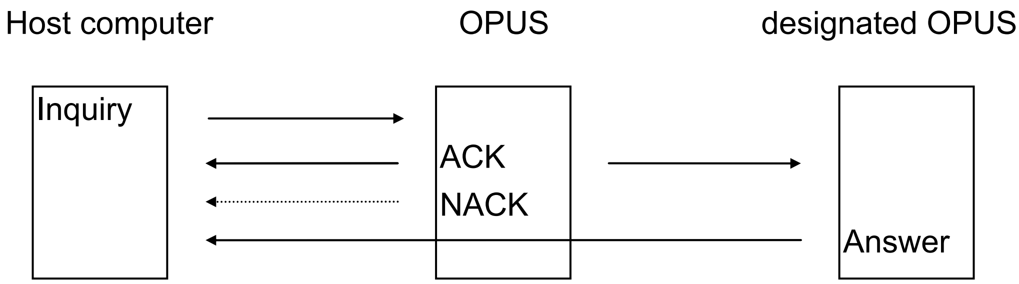
9.4 Binary protocol (IRS-21 over OPUS200/300 <-> host computer)

9.4.1 Physical connection and hardware structure

The sensors are connected to the host system via OPUS200 modules. Each of these modules can bear 1 road senor or 2 standard sensors (temperature / humidity etc.) and they are connected among each other by CAN bus. Further modules can be added if necessary. Each of these modules can be used as interface to the host system with the exception of the ones which are connected to an intelligent road sensor. The connection is established through the RS232 interface. The baudrate is 19200 with 8 data bits, no parity and 1 stop bit (8N1). All sensors connected to the system can be addressed and read out via the RS232 connection.

9.4.2 Software protocol

The sensors are adressed and read out with a defined protocol through the host computer. The host computer will send an inquiry telegram in cyclical intervals to each OPUS200 in the system. If the OPUS which is connected to the serial interface has received the telegram correctly, it will send an ACK telegram. In case an error is detected, it will send a NACK telegram. If the telegram has been received correctly, the OPUS200 to which the inquiry was designated will answer by sending the current values to the host computer.
The polling has to be done synchronously. The sensors and transmitters will not initiate any messages on their own. The floating measurement values are mapped linearly to a normalised value range of 0 – 65520 (= standard transmission protocol), with 0 corresponding to the mimimum and 65520 to the maximum measurement value of the installed sensor. The values above 65520 are used as error codes.



9.4.3 Telegram and data format

9.4.3.1 Data format:

LONG: LowLowByte LowHighByte HighLowByte HighHighByte

INT: LowByte HighByte

9.4.3.2 Telegram format

Inquiry telegram

Byte	1	2	3	4	5	6	7	8
Online data inquiry	?	N	x	x	x	x	c	c

x : Address of the OPUS200 as LONG

cc: sum of all preceeding bytes as INT (LSB first)

Answering telegram

Byte	1	2	3	4	5	6	7	8	9	10	11	12
Online data answer at up to 4 measured values,	?	N	v1	v1	v2	v2	v3	v3	v4	v4	c	c
in case of more than 4 measured values, a second telegram will follow	?	N	v5	v5	v6	v6	v7	v7	c	c	-	-

v1 – v7: Maximum of 7 measurement values, each as INT.

The number of measurement values transmitted by an OPUS depends on the respective configuration. If the OPUS provides only average values over the storage interval, only the measurement values v1 and v2 will be sent. If the minimum and/or maximum values of the storage interval shall also be delivered, the number of values increases to 4 or 6, respectively..

When an IRS-21 is connected to an OPUS (see Chapter 10.4.3.3), a maximum of 7 measurement values can be transmitted.

cc: sum of all preceeding bytes as INT (LSB first)

ACK / NACK Telegram following an online inquiry

Byte	1	2	3	4	5
ACK Telegram	$	?	N	c	c
NACK Telegram	#	?	N	c	c

cc: sum of all preceeding bytes as INT (LSB first)

9.4.3.3 Special case Intelligent Road Sensor (IRS-21)

An OPUS200 which has been configured for connecting an Intelligent Road Sensor uses the same telegram format for transmitting data as do the OPUSses with standard sensors. When the OPUS with the IRS receives an inquiry, it will send 2 telegrams with a total of 6 or 7 measurement values. In contrast to the standard OPUS 200, these measurement values are not the average, maximum and minimum values, but have special meanings, which are :

v1: internal temperature sensor IRS21 -50 °C – 150 °C
v2: external temperature sensor 1 IRS21 -50 °C – 150 °C
v3: external temperature sensor 2 IRS21 -50 °C – 150 °C
v4: Freezing temperature -25 °C – 0 °C

At configuration for transmitting the normalized water film height:

v5: Normalized water film height	0 - 250
v6: Water film height	0 – 4000 µm
v7: Road condition	0 – 99

At configuration without transmitting the water film height:

v5: Water film height	0 - 4000 µm
v6: Road condition	0 – 99

All measurement values with the exception of the road condition are transferred in the standard transmission protocol (see Chapter 10.4.2) and have to be converted accordingly. The road condition is transmitted directly (i.e. 0 – 99)

9.4.3.4 Error codes

The following error codes have been defined:

Designation	Value	
Value Overflow	0xFFF3	The measured value is above or below the sensor entrance range, or no is sensor connected
Conf Error	0xFFF4	An invalid configuration has been detected.
Xor Error	0xFFF5	The check sum over the E2 is wrong.
Invalid Value	0xFFFD	

9.4.4 Configuration of the OPUS200 modules

The configuration of an OPUS200 is carried out using the software SmartControl. SmartControl provides for the configuration of all sensors except the Intelligent Road Sensor. The configurations of the OPUS200 has influences directly the size and the number of the answering telegrams following an online inquiry (see telegram format of answering telegrams)

9.4.5 Configuration of the Road Sensor

Any OPUS 200 which is supposed to communicate to a road sensor has to be configured manually. This is carried out in the monitor mode by setting E2 address no. 368 to the value of 98 (connect the OPUS200 to the serial interface, and switch it into the monitor mode with !xxxxx (xx = id of the OPUS). The OPUS should send a small message to the terminal program)

In the monitor mode use the command

ES 368 98

to write the value into the E2 address.

By setting E2 address no. 367 the output format can be defined. If this address carries the value of 98, the normalized water film height will not be transferred and the codification of the road condition is changed. (Command: **ES 367 98**)

After the following re-start "FASS" should be displayed on the OPUS.

An OPUS that is configurated for the road sensor has the following settings:

Measuring interval	60 seconds
Storage interval	10 minutes
Mode	Sleep mode

The provided values (see telegram format: Special case Intelligent Road Sensor) have the following meaning:

v1: internal temperature sensor	Road surface temperature in the range -50°C - 150°C
v2: external temperature sensor 1	Temperature of the first external temperature sensor in the range -50°C - 150°C
v3: external temperature sensor 2	Temperature of the second external temperature sensor in the range -50°C - 150°C
v4: Freezing temperature	Freezing temperature of the salt solution on the street in the range -25°C - 0°C

Configuration for transferring the normalized water film height (E2 address 367 - value unequal to 98)

v5: normalized water film height	(Qualitative Water film height)	
	0	much water
	150	no water
	250	much ice
v6: Water film height	Water film height between 0 and 4000 µm	
v7: Road condition		Road condition
	0	dry
	1	damp
	2	wet
	3	ice
	4	frost / snow
	5	residual salt
	6	freezing wet
	99	Road condition cannot be determined

Configuration without transferring the normalized water film height (E2 address 367 – value equal to 98):

v5: Water film height	Water film height between 0 and 4000 µm	
v7: Road condition		Road condition
	1	dry
	2	wet
	3	ice
	4	damp
	5	residual salt
	6	freezing wet
	99	Road condition cannot be determined

Enclosure

CRC-Calculation For IRS-20/21

The checksum is calculated according to the following rules:

Polynomial: 1021h = $x^{16} + x^{12} + x^{5} + 1$ (LSB-first-mode)

Start value: 0000h

(Note: Unlike the checksum calculation of the UMB-protocol the start value is not FFFFh but 0000h! The UMB-protocol is used by devices clearly marked with the UMB logo.)

Please note that the checksum calculation starts with the second byte of the datagram.

Example

When calculating the checksum for several bytes the previously calculated checksum need to be stored temporarily in an unsigned short variable. In the beginning, this variable has to be initialized by 0000h.

```
/**************************************************************************
Function:     16 Bit CRC-Calculation For IRS-20/21
--------------------------------------------------------------------------
Parameter:    calc_crc(unsigned short crc_buff, unsigned char input)
--------------------------------------------------------------------------
Return:       CRC checksum
--------------------------------------------------------------------------
Diskription:  Calculates CRC checksum using polynomial x^16 + x^12 + x^5 + 1
              'crc_buff' holds the temporarily calculated checksum for 'input'.
              'crc_buff' has to be initialized by 0x0000.
**************************************************************************/
unsigned short calc_crc(unsigned short crc_buff, unsigned char input)
{
      unsigned char i;
      unsigned short x16; // we will use this to hold the XOR mask
      for (i=0; i<8; i++)
      {
            // XOR current D0 and next input bit to determine x16 value
            if( (crc_buff & 0x0001) ^ (input & 0x01) )
                  x16 = 0x8408;
            else
                  x16 = 0x0000;
            // shift crc buffer
            crc_buff = crc_buff >> 1;
```

```
            // XOR in the x16 value
            crc_buff ^= x16;
            // shift input for next iteration
            input = input >> 1;
      }
      return(crc_buff);
}


// ****************** MAIN **********************************
void main(void)
{
      // example: CRC for 8 Bytes
      unsigned char values[8] =
            {0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37};
      // initialise startvalue 0000h
      unsigned short crc = 0x0000;
      // calculation
      for(int n = 0; n < 8; n++)
      {
            crc = calc_crc(crc, values[n]);
      }
      // output
      printf("\ndata:  30h, 31h, 32h, 33h, 34h, 35h, 36h, 37h");
      printf("\nCRC:   %04Xh\n", crc);
}
```

Output:

```
data:  30h, 31h, 32h, 33h, 34h, 35h, 36h, 37h
CRC:   84CFh
```

10 Compliance Statement

USA

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.

Usually this is followed by the following FCC caution:

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

Kanada

Operation is subject to the following two conditions:

(1) this device may not cause interference, and

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

Usually this is followed by the following RSS caution:

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.