CO2 TRANSDUCER

CO2-SENS-D-MODRTU

1. Introduction

This document describes functionality of CO_2 concentration transducer based on integrated MH-Z19B sensor, equipped with RS-485 interface using MODBUS RTU protocol and 0-5V / 0-10V analogue output.

NOTES:

1) Read this document carefully before attempting to start up the device!

2) The device must be installed by qualified staff only.

1.1. Functions of the device

- CO_2 measurement
- 0-5V or 0-10V analogue output (hardware selectable range) proportional to CO_2 concentration
- 3 status LEDs
- RS485 serial interface for remote management (setup and reading of measurement values)
  - MODBUS RTU protocol
  - integrated terminating resistor 120Ω
  - communication in HALF DUPLEX mode
  - hardware/software configurable address in the range 1-247
  - hardware configurable communication baud rate: 19200, 9600, 4800, 2400
  - software configurable communication baud rate: 115200, 57600, 38400, 19200, 9600, 4800, 2400

1.2. Device characteristics

The main function of the CO_2 transmitter is to measure the CO_2 concentration in the air using an integrated MH-Z19B sensor. The measurement result, as well as the sensor missing/error status, is processed by the built-in microprocessor and then made available on the RS-485 bus via registers of the MODBUS RTU protocol. Additionally, the measurement result is available as analog signal on the 0-5V / 0-10V voltage output.

2. Technical data

2.1. General parameters of the transducer

Power supply	
• DC voltage	DC 20-30 V (nom DC 24 V)
• AC voltage	AC 20-28 V (nom AC 24 V)
Current consumption	
• typical	30 mA
• max	100 mA
LED indicators	See section 3.5
Signal connection	Screw terminals in 5 mm pitch (wire diameter ≤ 2.5 mm)
Housing dimensions	
• without sampling mast	80x82x55 mm
• with sampling mast	80x82x280 mm
Weight	230g
Working environment	Dust-free, air, neutral gases
Working temperature	0ºC ÷ 50ºC

2.2. Parameters of CO2 measurement

Sensor model	MH-Z19B
Measurement range	0/400-2000 ppm
Measurement accuracy	± (5% of measured value + 50ppm)
Sampling period	5 s
Response time T90 *)	< 2 min

*) response time T90 is the time from moment of change of state to the moment when the measurement value reaches 90% of the steady value.

2.3. Parameters of analogue output

Output type	voltage
Output range	0-5 V or 0-10 V
Resolution	11.5 bit
• in [mV] for the range 0-10 V	3.2 mV~
• in [mV] for the range 0-5 V	1.6 mV~
Loading capacity	RL > 1 kΩ
Refreshing period	1 s

2.4. Parameters of serial interface

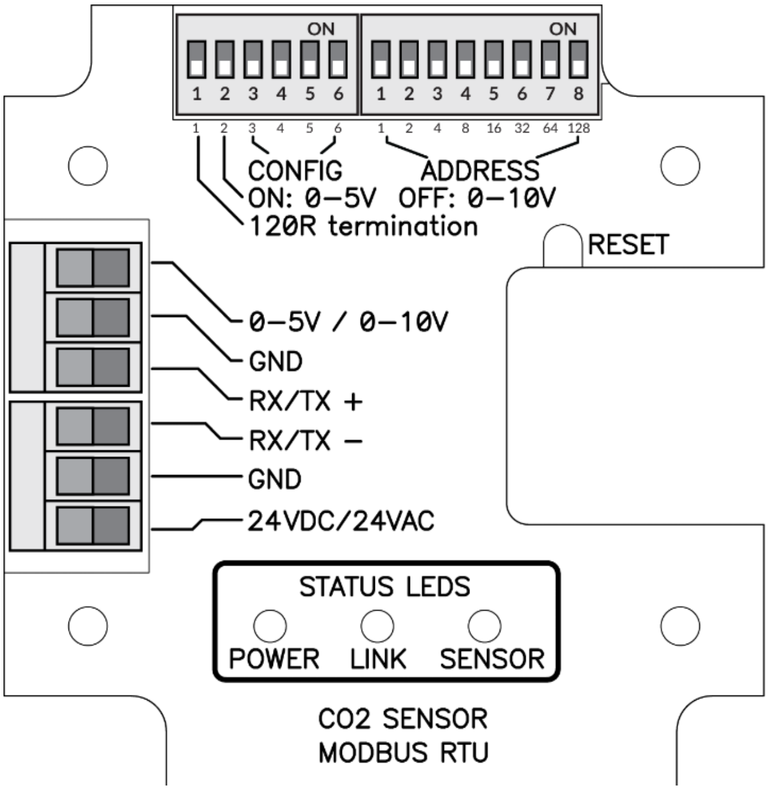
Transmission interface	RS-485
Communication protocol	MODBUS RTU
Transmission type	HALF DUPLEX
Communication baud rate	2400 / 4800 / 9600 / 19200 / 38400 / 57600 / 115200 Baud/s
Integrated resistor terminating the RS-485 bus	120 Ω

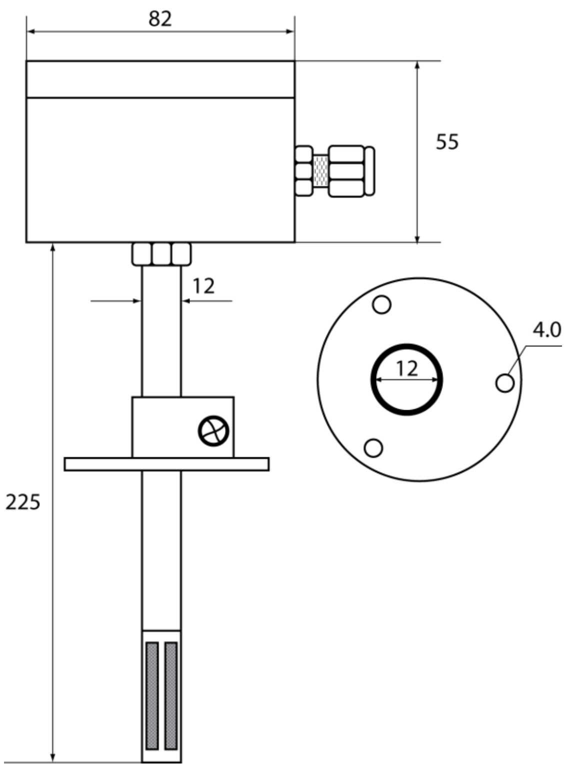
3. Installation

3.1. Safety

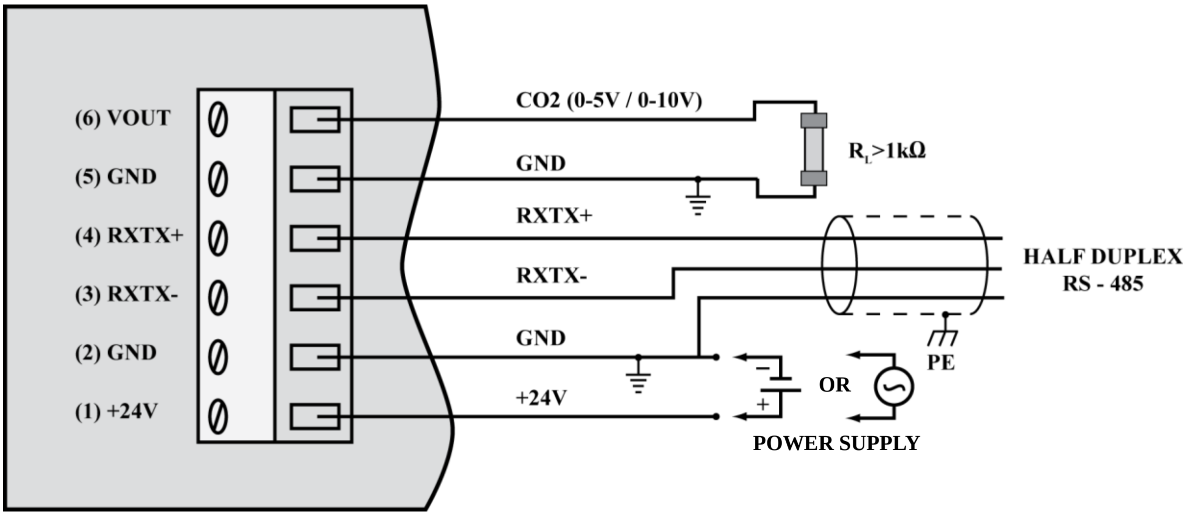
- **The device must be installed by qualified staff only!**
- **All connections must be made in accordance with wiring diagrams shown in this document!**
- **Check all electrical connections prior to commissioning!**

3.2. Device design





3.3. Description of terminals



Notes:
1. The RXTX+ and RXTX- signals must be connected to the A and B lines of the MODBUS bus respectively.
2. The analogue output returns following voltage values:

$$V_{out} = \frac{VOLTAGE_{RANGE}}{2000\ ppm} \cdot CO2_{CONCENTRATION}$$

whereas the concentration value can be calculated basing on the voltage value form using the following formula:

$$CO2_{CONCENTRATION} = \frac{2000\ ppm}{VOLTAGE_{RANGE}} \cdot V_{OUT}$$

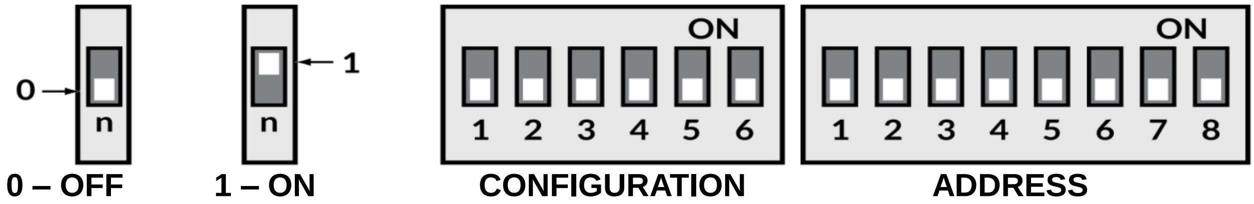
where:

VOLTAGE$_{RANGE}$ = 5V or 10V (0-5V or 0-10V set on the configuration DIP-switch 2 – see section 3.4)

Exemplary values are shown in the table below:

CO2 concentration [ppm]	Voltage range = 5 V	Voltage range = 10V
0	0.0V	0.0V
400	1.0V	2.0V
1000	2.5V	5.0V
2000	5.0V	10.0V

3.4. Configuration of MODBUS bus, serial port and analogue output



The purpose of the consecutive switches of the left DIP-switch is as follows (default values are in bold)

1	2	3	4	5	6	Effect
ON						Terminating resistor 120R switched on
OFF						**Terminating resistor 120R switched off**
	ON					Analogue output range 0-5V
	OFF					**Analogue output range 0-10V**
		ON	ON			Use BAUDRATE and PAR from the software configuration
		ON	OFF			PAR - parity check (1 STOP bit)
		OFF	ON			PAR - no parity check (2 STOP bits)
		OFF	**OFF**			**PAR - no parity check (1 STOP bit)**
				ON	ON	BAUDRATE=2400
				ON	OFF	BAUDRATE=4800
				OFF	ON	BAUDRATE=9600
				OFF	**OFF**	**BAUDRATE=19200**

The device address on the MODBUS bus is set using the right DIP-switch:

1	2	3	4	5	6	7	8	Effect
ON								**Address = address + 1**
	ON							**Address = address + 2**
		ON						**Address = address + 4**
			ON					**Address = address + 8**
				ON				**Address = address + 16**
					ON			**Address = address + 32**
						ON		**Address = address + 64**
							ON	**Address = address + 128**

Note: the configuration set by the means of DIP-switches is read once after device restart (after switching on the power or pressing the RESET button). For this reason, if the DIP-switch settings are changed during operation, then after changing the settings, it is necessary to restart the device by pressing the RESET button or temporarily unplugging the power supply.

3.5. LED indicators

3.5.1. LED POWER

No.	Description	Color / mode of light
1	Power supply present	Red – flashing 1000 ms / 1000 ms

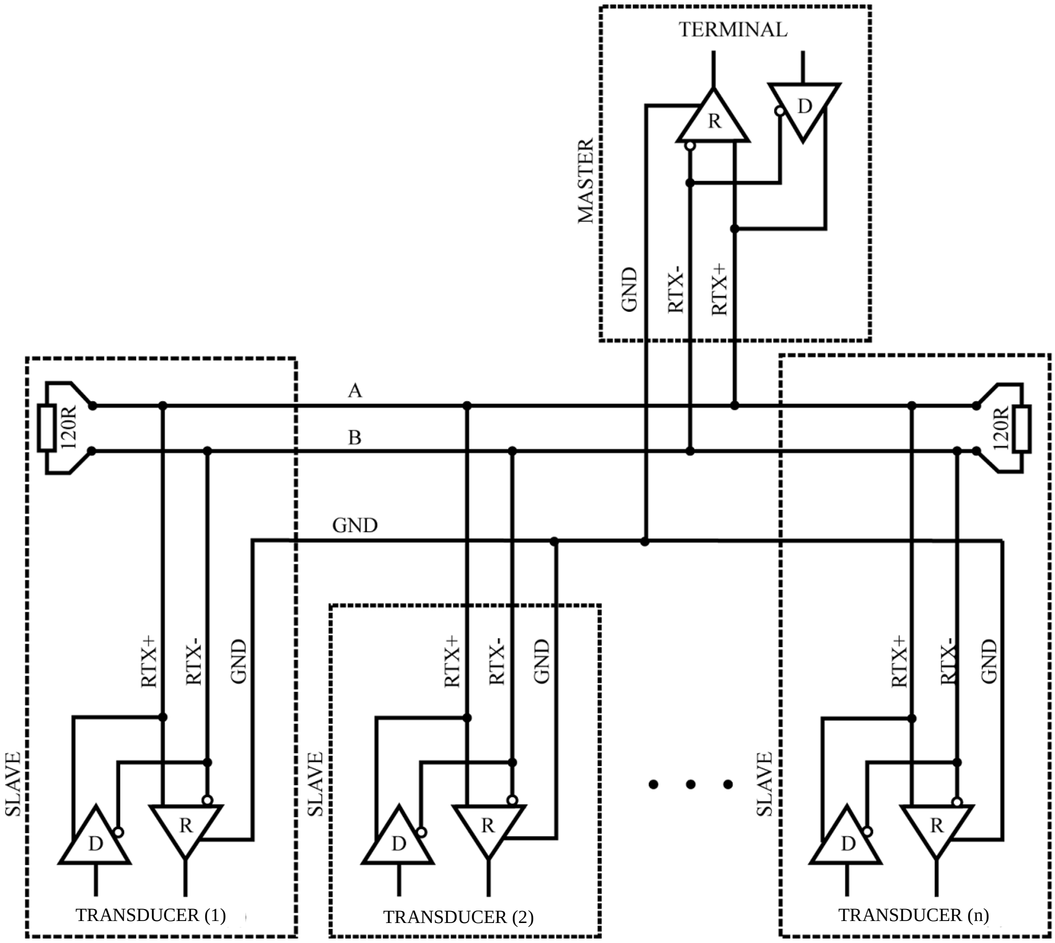
3.5.2. LED LINK

No.	Description	Color / mode of light
1	Data transmission on the bus	Green – continuous light / irregular flashing
2	No transmission	LED off

3.5.3. LED SENSOR

No.	Description	Color / mode of light
1	Warm up of the CO2 module	Green – flashing 250 ms / 250 ms
2	0 – 799 ppm	Green – continuous light
3	800 – 1199 ppm	Yellow – continuous light
4	1200 – 1999 ppm	Red – continuous light
5	≥ 2000 ppm	Red – flashing 1000 ms / 1000 ms
6	Sensor missing or other error	Red – flashing 100 ms / 600 ms

3.6. Recommendations for installation



It is recommended that devices on the MODBUS (RS485) are connected in a daisy-chain configuration, whereby 120R terminating resistors should be connected between A and B lines of the bus at both ends of the chain (close to the outer devices). This resistor is built-in in the CO2-SENS-D-MODBRTU transducer and can be switched on using the no. 1 switch on the configuration DIP-switch (see section 3.4).

Moreover, shielded cables should be used when the device is operated in high interference environments and the shield should be connected to the nearest PE point on the power supply side.

3.7. The automatic zero calibration (ABClogic function)

It is assumed that CO2 concentration in the outdoor air amounts to 400 – 500 ppm. The CO2 concentration inside buildings is higher, mainly due to the presence of people. When there are no people in the building and the ventilation systems works properly, the CO2 concentration inside the building decreases to a level close to those of outdoor air.

ABClogic is an algorithm for long term tracking of CO_2 concentration and adjusting the sensor characteristics in the low concentration range. The sensor stores low values of CO_2 concentration from many last days, which enables taking intelligent account of periodical CO_2 concentration level increases (e.g. when rooms were used 24 hours per day over a few days). As a result of the ABClogic algorithm, the “automatic zero calibration” of the sensor is carried out.

The automatic calibration ABClogic, is designed for applications where rooms remain unoccupied for several hours per day, as a result, CO_2 concentration values periodically drop to low values, similar to those outside the building. In contrast, in an environment where the level of CO_2 concentration reaches high values and doesn't drop to low values, the ABClogic system should be switched off, because it would adjust automatic calibration to the lowest levels, distorting the values indicated by the sensor.

In the sensor described in this document, the ABClogic function is off by default (factory setting). The status of ABClogic function (switching on or off) can be changed by writing the respective command (see section 4.1.1).

4. MODBUS protocol

4.1. Register map

Register no.	R/W	Name	Values	Notes
0x0000	R	VALUE_REG	0 - 2000	CO_2 concentration in [ppm]
0x0001	R	STATUS_REG	0 / 1 / 2 / 3	0-Sensor missing, 1 – correct operation, 2 – sensor error, 3 – warm up (first 3 minutes after start)
0x0002	R	TEST_VAL_REG	1000 (0x3E8)	Test value – to verify the correctness of register readings
0x0003	RW	PASS_REG	1234 (0x04D2)	password register
0x0004	RW	COMMAND_REG	1 / 2 / 3 / 4 / 5 / 6	command register
0x0005	RW	PARAM_REG	Refer to command table	parameter register
0x0006	R	--	0	reserved
0x0007	R	--	0	reserved
0x0008	R	--	0	reserved
0x0009	R	--	0	reserved
0x000A	R	--	0	reserved
0x000B	R	DEV_ID_REG	0xC100	Device identification
0x000C	R	SOFT_VER_REG	0 – 0x9999	Software version (e.g. 0x3210 means software 3.21a)

Command table:

Command no.	Function	Parameters
1	Set device address	1-247 (1 – default value)
2	Set the baud rate	24 – 2400 bit/s 48 – 4800 bit/s 96 – 9600 bit/s 192 – 19200 bit/s = default value 384 – 38400 bit/s 576 – 57600 bit/s 1152 – 115200 bit/s
3	Set parity bits	0 – NO PARITY, no parity bit (default value) 1 – EVEN PARITY 2 – ODD PARITY
4	Set stop bits	1 – 1x STOP, 1 stop bit (default value) 2 – 2x STOP, 2 stop bits
5	Function on / off	0 – ABClogic off (off by default) 1 – ABClogic on
6	Device reset	1 – software reset of the device 2 – software reset of sensor module

Notes:

- Reading registers from addresses not listed in this table results in 0x02 exception.
- Specifying an incorrect or out-of-range parameter value results in entering the value 0xEEEE into the command register.
- The device is configured by writing three registers (password / command / parameter) at the same time using the 0x10 function with the corresponding values – according to the command table, or by writing single registers (using 0x06 or 0x10 function) with the latter writing of a (valid) password causing the execution of the command.
- During a single password entry (both with function 0x06 and 0x10) in case of a password match, the correctness of information in command and parameter registers is checked and if correct, the command is executed.

4.1.1. DEV_ID_REG (addr=11=0x000B) – read only

Bit no.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
name	DEV[4..0]					HV[1..0]		OPTIONS[4..0]					0	0	T[1..0]	

This register is used to store device ID. Meaning of bits:
DEV[4..0] = b11000 – fixed value meaning "air parameter sensors"
HV[1..0] – value 0..3 – hardware version
OPTIONS[4..0] – values 0..31 – device type
b10000 – CO2 transducer with MH-Z19B sensor
T[1..0] – value 0..3 – type
0 – duct type
1 – room type
2, 3 - reserved

CO2 duct sensor in basic hardware version returns the value b1100000100000000=0xC100.

4.1.2. SOFT_VER_REG (addr=12=0x000C) – read only

Bit no.	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
name	N[3..0]				A[3..0]				B[3..0]				REV[3..0]			

Software version is represented as a sting of 4 characters: N.ABrev
where
N, A, B are digits in the the 0..9 range
rev (with values 0..9) is a letter in the range 'a'...'j'.
Examples:
0x0000 represents software version: 0.00a; 0x4321 → 4.32b ; 0x2345 → 2.34f

4.2. Protocol functions

CODE	Name
0x03 (dec 3)	Reading N x 16-bit registers
0x06 (dec 6)	Writing single 16-bit registers
0x10 (dec 16)	Writing N x 16-bit registers

4.2.1. Reading the contents of a group of output registers (0x03)

Command format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x03**	
Data block address	2	0x0000 – 0xFFFF	
Number of registers (N)	2	1 – 125	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Response format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x03**	
Byte counter	1	2* n	
Register values	2 * N	Acc. to register map	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Error format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x83**	
Error code	1	1– 4	See section 4.2.4
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

4.2.2. Writing single 16-bit registers (0x06)

Command format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x06**	
Register address	2	0x0000 – 0xFFFF	
Value to be stored	2	0x0000 – 0xFFFF	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Response format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x06**	
Register address	2	0x0000 – 0xFFFF	
Value to be stored	2	0x0000 – 0xFFFF	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Error format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x86**	
Error code	1	1 – 4	See section 4.2.4
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

4.2.3. Writing a group of output registers (0x10)

Command format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x10**	
Data block address	2	0x0000 – 0xFFFF	
Number of registers (N)	2	1 – 123	
Byte counter	1	2 * N	
Values to be stored	2 * N	0x0000 – 0xFFFF	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Response format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x10**	
Data block address	2	0x0000 – 0xFFFF	
Number of registers (N)	2	1 – 123	
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

Error format:

Description	Size [Bytes]	Values	Notes
Address	1	1 – 247	
Function code	1	**0x90**	
Error code	1	1 – 4	See section 4.2.4
CRC check sum	2	0x0000 – 0xFFFF	See section 4.4

4.2.4. Description of errors

CODE	Name
0x01	Invalid function
0x02	Invalid data range / address
0x03	Invalid data value
0x04	SLAVE device error

4.3. Data format

4.3.1. Character / byte format

The following figure shows the format of a byte transmitted in the MODBUS RTU protocol. Each transmitted character has 10 or 11 bits, which are sent in order from the least significant to the most significant.

With even / odd parity check

START	1	2	3	4	5	6	7	8	PAR	STOP

Without parity check (1 or 2 stop bits):

START	1	2	3	4	5	6	7	8	STOP	(STOP)

4.3.2. Order of bytes in 16-bit data fields in a transmission frame

The following figure shows the byte order of the 16-bit data fields. For 16-bit data fields, the correct byte order is that the older byte is transmitted first, then the younger byte (HI→LO - BIG ENDIAN), while for the CRC field the younger byte is transmitted first, then the older byte (LO→ HI - LITTLE ENDIAN).

DATA								CHECK SUM	
REG-0 (16bit)		REG-1 (16 bit)		...	REG-N (16bit)			CRC (16bit)	
HI	LO	HI	LO		HI	LO		LO	HI

4.4. CRC check sum

```
WORD CRC16 (const BYTE *nData, WORD wLength)

{
static const WORD wCRCTable[] = {
0x0000, 0xC0C1, 0xC181, 0x0140, 0xC301, 0x03C0, 0x0280, 0xC241, 0xC601, 0x06C0, 0x0780, 0xC741, 0x0500, 0xC5C1,
0xC481, 0x0440, 0xCC01, 0x0CC0, 0x0D80, 0xCD41, 0x0F00, 0xCFC1, 0xCE81, 0x0E40, 0x0A00, 0xCAC1, 0xCB81,
0x0B40, 0xC901, 0x09C0, 0x0880, 0xC841, 0xD801, 0x18C0, 0x1980, 0xD941, 0x1B00, 0xDBC1, 0xDA81, 0x1A40,
0x1E00, 0xDEC1, 0xDF81, 0x1F40, 0xDD01, 0x1DC0, 0x1C80, 0xDC41, 0x1400, 0xD4C1, 0xD581, 0x1540, 0xD701,
0x17C0, 0x1680, 0xD641, 0xD201, 0x12C0, 0x1380, 0xD341, 0x1100, 0xD1C1, 0xD081, 0x1040, 0xF001, 0x30C0,
0x3180, 0xF141, 0x3300, 0xF3C1, 0xF281, 0x3240, 0x3600, 0xF6C1, 0xF781, 0x3740, 0xF501, 0x35C0, 0x3480, 0xF441,
0x3C00, 0xFCC1, 0xFD81, 0x3D40, 0xFF01, 0x3FC0, 0x3E80, 0xFE41, 0xFA01, 0x3AC0, 0x3B80, 0xFB41, 0x3900, 0xF9C1,
0xF881, 0x3840, 0x2800, 0xE8C1, 0xE981, 0x2940, 0xEB01, 0x2BC0, 0x2A80, 0xEA41, 0xEE01, 0x2EC0, 0x2F80, 0xEF41,
0x2D00, 0xEDC1, 0xEC81, 0x2C40, 0xE401, 0x24C0, 0x2580, 0xE541, 0x2700, 0xE7C1, 0xE681, 0x2640, 0x2200, 0xE2C1,
0xE381, 0x2340, 0xE101, 0x21C0, 0x2080, 0xE041, 0xA001, 0x60C0, 0x6180, 0xA141, 0x6300, 0xA3C1, 0xA281, 0x6240,
0x6600, 0xA6C1, 0xA781, 0x6740, 0xA501, 0x65C0, 0x6480, 0xA441, 0x6C00, 0xACC1, 0xAD81, 0x6D40, 0xAF01,
0x6FC0, 0x6E80, 0xAE41, 0xAA01, 0x6AC0, 0x6B80, 0xAB41, 0x6900, 0xA9C1, 0xA881, 0x6840, 0x7800, 0xB8C1,
0xB981, 0x7940, 0xBB01, 0x7BC0, 0x7A80, 0xBA41, 0xBE01, 0x7EC0, 0x7F80, 0xBF41, 0x7D00, 0xBDC1, 0xBC81,
0x7C40, 0xB401, 0x74C0, 0x7580, 0xB541, 0x7700, 0xB7C1, 0xB681, 0x7640, 0x7200, 0xB2C1, 0xB381, 0x7340, 0xB101,
0x71C0, 0x7080, 0xB041, 0x5000, 0x90C1, 0x9181, 0x5140, 0x9301, 0x53C0, 0x5280, 0x9241, 0x9601, 0x56C0, 0x5780,
0x9741, 0x5500, 0x95C1, 0x9481, 0x5440, 0x9C01, 0x5CC0, 0x5D80, 0x9D41, 0x5F00, 0x9FC1, 0x9E81, 0x5E40, 0x5A00,
0x9AC1, 0x9B81, 0x5B40, 0x9901, 0x59C0, 0x5880, 0x9841, 0x8801, 0x48C0, 0x4980, 0x8941, 0x4B00, 0x8BC1, 0x8A81,
0x4A40, 0x4E00, 0x8EC1, 0x8F81, 0x4F40, 0x8D01, 0x4DC0, 0x4C80, 0x8C41, 0x4400, 0x84C1, 0x8581, 0x4540, 0x8701,
0x47C0, 0x4680, 0x8641, 0x8201, 0x42C0, 0x4380, 0x8341, 0x4100, 0x81C1, 0x8081, 0x4040};

BYTE nTemp;
WORD wCRCWord = 0xFFFF;

  while (wLength--)
  {
    nTemp = *nData++ ^ wCRCWord;
    wCRCWord >>= 8;
    wCRCWord ^= wCRCTable[nTemp];
  }
  return wCRCWord;

}
```