MODBUS Protocol

Preface

This document describes the implementation of the MODBUS protocol in the Scancon eCODE Series of communicating encoders. It is not intended to be a description of the MODBUS protocol itself as information about this can be found elsewhere. For additional information about the protocol, visit the Modbus-IDA organization at www.modbus.org.

This is the first revision of this document and should, in some aspects, be considered to be preliminary as more functionality of the eCODE Encoders may be added in the future. It is, though, the intention that all functionality described in this revision will be kept unchanged in future versions and new functionality will be implemented as additions.

1.0 Introduction

The implementation of the MODBUS protocol in the Scancon eCODE Series of encoders follows in widest possible way the requirements and recommendations as defined in the latest protocol specifications from the MODBUS organization. The specifications "MODBUS Application Protocol Specifications V1.1b" and "MODBUS over Serial Line Specifications and Implementation Guide V1.02" can both be found at www.modbus.org.

The transmission mode used for the eCODE Encoders is MODBUS RTU.
Broadcast messages are accepted but not used, i.e. the encoder will not perform any action to a broadcast message.

The eCODE Encoders contain both single register (16 bit) and double register (32 bit) values.

Throughout this description most values will be written in both decimal and hexadecimal notation. Hexadecimal notation will be indicated by a "0x" and surrounded by parenthesizes.
0x## indicates a byte value (8 bits), 0x#### indicates a word value (16 bits) and 0x####.#### indicates a double word value (32 bits).

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2.0 Communication Settings

2.1 Serial Line Format

The serial line format is 8E1 meaning 8 data bits, even parity and 1 stop bit.

2.2 Baud Rates

The baud rate can be set to any common baud rate between 2400 baud and 3.68 Mbaud. The maximum useable baud rate will, however, be limited by the length and the quality of the transmission cable.

2.3 Data Encoding

All transmitted or received register values are in big-Endian format. This means that for single register values (16 bits) the first byte represents the most significant byte (MSB) and the second byte represents the least significant byte (LSB). For double register values (32 bits) the first (lowest numbered) register represents the most significant word (MSW) and the second (highest numbered) register represents the least significant word (LSW).

2.4 Message Framing

The message framing used by the eCODE Encoders follows the latest guidelines and recommendations set up by the MODBUS organization in the following way:

For baud rates below or equal to 19,200 baud.

Inter-character time-out (t1.5)	=	1.5 character times.
Inter-frame delay (t3.5)	=	3.5 character times.

For baud rates above 19,200 baud.

Inter-character time-out (t1.5)	=	750 µSec.
Inter-frame delay (t3.5)	=	1750 µSec.

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3.0 Exception Codes

The eCODE Encoders support the following exception codes:

- Exception Code 01 (0x01) — Illegal Function.
  The function is not supported by the encoder.
- Exception Code 02 (0x02) — Illegal Data Address.
  The register address is not defined in the encoder.
- Exception Code 03 (0x03) — Illegal Data Value.
  Fault in the data field structure of the request.

4.0 Function Codes

The eCODE Encoders support the following function codes:

- Function Code 03 (0x03) — Read Holding Registers
- Function Code 04 (0x04) — Read Input Registers
- Function Code 06 (0x06) — Write Single Register
- Function Code 16 (0x10) — Write Multiple Registers
- Function Code 17 (0x11) — Report Slave ID

An attempt to send a request with a function code that is not supported will return an exception response with the exception code 01.

5.0 Register Definitions

The implementation of the MODBUS protocol in the Scancon eCODE Series of encoders uses Input Registers and Holding Register.

In the following description of register addresses the number in square brackets denotes the now obsolete method of indicating to which group a given register belongs. This is only shown for historical reasons as the latest MODBUS protocol specification does not use this method of register grouping.

An attempt to address a register that is not defined will return an exception response with the exception code 02. If a register in a request that attempts to write several registers (function code 16) is not defined, the whole request will be rejected, i.e. no registers that are specified in the request will be written.

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5.1 Input Registers [3xxxx Registers]

Description of Defined Input Registers.

For those Input Registers that are part of a multi-register position value all registers must be read and read in the correct order to assure time consistent register values. The returned position value is sampled when the first register is read.

Notice, that some registers have been mirrored to take advantage of the ability of the MODBUS protocol to read several registers in one request.

Register no.	Name	Description
1 [30001]	Multiturn Position – Signed	High word of position
2 [30002]	Multiturn Position – Signed	Low word of position
3 [30003]	Status Register	Status of encoder
6 [30006]	Multiturn Position – Unsigned	High word of position
7 [30007]	Multiturn Position – Unsigned	Low word of position
8 [30008]	Status Register	Status of encoder
11 [30011]	Revolutions – Unsigned	Number of full revolutions
12 [30012]	Singleturn Position – Unsigned	High word of position
13 [30013]	Singleturn Position – Unsigned	Low word of position
14 [30014]	Status Register	Status of encoder
16 [30016]	Singleturn Position – Unsigned	High word of position
17 [30017]	Singleturn Position – Unsigned	Low word of position
18 [30018]	Status Register	Status of encoder
21 [30021]	Revolutions - Unsigned	Number of full revolutions
22 [30022]	Status Register	Status of encoder
31 [30031]	Temperature	Temperature inside encoder
32 [30032]	Supply Voltage	Supply voltage of encoder
33 [30033]	Rotation Speed	Rotation speed as RPM
34 [30034]	Operational Time	Operational time as hours

Register 1-2 – Multiturn Position – Signed

A read operation from these registers will return the signed multiturn position. Both registers must be read and the reading order must always be Register1 – Register 2. It is recommended to read both registers in one request.

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The returned value is the multiturn position after it has been scaled according to the "Positions per Revolution" parameter (see below under Holding Registers and Appendix A).

Register 3 – Status Register

A read operation from this register returns a 16 bit value where every bit indicates the status of a specified condition. For a definition of the status bits, refer to Appendix B.

Register 6-7 – Multiturn Position – Unsigned

A read operation from these registers will return the unsigned multiturn position. Both registers must be read and the reading order must always be Register 6 – Register 7. It is recommended to read both registers in one request.

The returned value is the multiturn position after it has been scaled according to the "Positions per Revolution" parameter (see below under Holding Registers and Appendix A).

Register 8 – Status Register

See description for Register 3.

Register 11-13 – Revolutions/Singleturn Position – Unsigned

A read operation from these registers will return the unsigned number of full revolutions and the unsigned singleturn position. All three registers must be read and the reading order must always be Register11 – Register 12 – Register 13. It is recommended to read all three registers in one request.

The returned values are the number of revolutions and the singleturn position after it has been scaled according to the "Positions per Revolution" parameter (see below under Holding Registers and Appendix A).

Register 14 – Status Register

See description for Register 3.

Register 16-17 – Singleturn Position - Unsigned

A read operation from these registers will return the singleturn position. Both registers must be read and the reading order must always be Register 16 – Register 17. It is recommended to read both registers in one request.

The returned value is the singleturn position after it has been scaled according to the "Positions per Revolution" parameter (see below under Holding Registers and Appendix A).

Register 18 – Status Register

See description for Register 3.

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Register 21 – Revolutions – Unsigned

A read operation from this register will return the number of full revolutions (refer to Appendix A).

Register 22 – Status Register

See description for Register 3.

Register 31 – Temperature

A read operation from this register will return the temperature inside the encoder. The units are °C. 30°C will therefore be reported as 30.

Register 32 – Supply Voltage

A read operation from this register will return the supply voltage of the encoder. The units are in 1/10V. 5.0V will therefore be reported as 50.

Register 33 – Rotational Speed

A read operation from this register will return the rotational speed of the encoder shaft or hollow shaft. The units are revolutions per minute (RPM).

Register 34 – Operational Time

A read operation from this register will return the operational time of the encoder. The units are hours. The operational time counter is running whenever the encoder is powered and the value will be maintained during power cycling.

5.2 Holding Registers [4xxxx Registers]

Description of Defined Holding Registers.

For Holding Registers that are part of a multi-register position preset, all registers must be written and in the correct order to assure time consistent position setting. The actual position setting takes place when the last register is written.

For Holding Registers that are part of a multi-register encoder setting value the reading or writing order is normally not important though it is recommended to access all multi-register values in one request.

For Holding Registers that have a defined range an attempt to write a value that is outside the defined range will be ignored (the value will not be written). The encoder will, though, issue a normal response.

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Values written to Holding Registers that contain encoder settings are saved in non-volatile memory (E^2Prom). It is therefore only necessary to write them once.

Register no.	Name	Description
1 [40001]	Multiturn Position	High word for preset of multiturn position
2 [40002]	Multiturn Position	Low word for preset of multiturn position
4 [40004]	Revolutions	Preset of full revolutions
5 [40005]	Singleturn Position	High word for preset of singleturn position
6 [40006]	Singleturn Position	Low word for preset of singleturn position
8 [40008]	Singleturn Position	High word for preset of singleturn position
9 [40009]	Singleturn Position	Low word for preset of singleturn position
11 [40011]	Revolutions	Preset of full revolutions
21 [40021]	Pos. per Revolution	High word of positions in one revolution
22 [40022]	Pos. per Revolution	Low word of positions in one revolution
23 [40023]	Direction of Rotation	Direction of rotation (CW or CCW)
24 [40024]	Compare Type	Compare type for max. and min. limits
25 [40025]	Max. Limit	High word of max. limit for position
26 [40026]	Max. Limit	Low word of max. limit for position
27 [40027]	Min. Limit	High word of min. limit for position
28 [40028]	Min. Limit	Low word of min. limit for position
29 [40029]	Calibration Position	High word of calibration position
30 [40030]	Calibration Position	Low word of calibration position
31 [40031]	Calibrate Procedure	Activate position calibration procedure
32 [40032]	Device Address	Address of encoder
33 [40033]	Baud Rate	Baud rate for communication
34 [40034]	Bus Termination	Enable/disable bus termination resistor

Register 1-2 – Multiturn Position

Writing to these registers will pre-set the multiturn position to the value written. Both registers must be written and the writing order must always be Register 1 – Register 2. It is recommended to write both registers in one request.

When presetting the multiturn position the encoder does not distinguish between signed or unsigned values. It is up to the master to express the position in the appropriate format.

Reading from these registers will always return 0 (0x0000.0000).

Range: Not defined (refer to Appendix A)
Default: N/A

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Register 4-6 – Revolutions/Singleturn Position

Writing to these registers will pre-set the number of revolutions and the singleturn position to the values written. All three registers must be written and the writing order must always be Register 4 – Register 5 – Register 6. It is recommended to write all three registers in one request.

Both the number of revolutions and the singleturn position are unsigned.

Reading from these registers will always return 0, 0 (0x000, 0x0000.0000).

Range: Revolutions : 0 (0x0000) – max. no. of revolutions - 1 (refer to Appendix D)
Singleturn: 0 (0x0000.0000) – programmed positions per revolution - 1 (Reg. 21-22)
Default: N/A

Register 8-9 – Singleturn Position

Writing to these registers will pre-set the singleturn position to the value written. Both registers must be written and the writing order must always be Register 8 – Register 9. It is recommended to write both registers in one request.

Presetting the singleturn position will not affect the value of the number of revolutions.
The singleturn position is unsigned.

Reading from these registers will always return 0 (0x0000.0000).

Range: 0 (0x0000.0000) – programmed positions per revolution - 1 (Reg. 21-22)
Default: N/A

Register 11 – Revolutions

Writing to this register will pre-set the number of revolutions to the value written.

Presetting the number of revolutions will not affect the value of the singleturn position.
The number of revolutions is unsigned.

Reading from this register will always return 0 (0x0000).

Range: 0 (0x0000) – max. no. of revolutions - 1 (refer to Appendix D)
Default: N/A

Register 21-22 – Positions per Revolution

Sets (scales) the number of positions for one revolution. This setting applies to both singleturn and multiturn use.

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Range: 1(0x0000.0001) – max. pos. per revolution (refer to Appendix D)
Default: 100000

Register 23 – Direction of Rotation

Sets the direction of rotation (the direction for incrementing the position value) of the encoder as clockwise (CW) or counter clockwise (CCW). The direction is as seen from the shaft side of the encoder.

CCW	=	0 (0x0000)
CW	=	any value different from 0

Note - even though a write of any value different from 0 will set to CW, a read will always return 65635 (0xFFFF) if the encoder is set for CW.

Range: 0 – 65635 (0x0000 – 0xFFFF)
Default: 65635 (CW)

Register 24 – Compare Type

Sets the compare type when comparing the position to the max. and min. limit (see below)

Signed Multiturn	=	1
Unsigned Multiturn	=	2
Singleturn only	=	3
Revolutions only	=	4

Range: 1 – 4 (0x0001– 0x0004)
Default: 1 (Signed Multiturn)

Register 25-26 – Maximum Limit

Sets the value to which the position is constantly compared. If the position is above the maximum limit value, the “Above Max. Limit” status bit (bit 3) is set.

It is up to the master to set this value in accordance with which compare type the encoder has been set to (Register 24).

Range: Depending on Compare Type (Register 24)
Default: 1000000

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Register 27-28 – Minimum Limit

Sets the value to which the position is constantly compared. If the position is below the minimum limit value, the "Below Min. Limit" status bit (bit 4) is set.

It is up to the master to set this value in accordance with which compare type the encoder has been set to (register 24).

Range: Depending on Compare Type (Register 24)
Default: 0

Register 29-30 – Calibration Position

Sets the value to which the position will be pre-set when the calibration procedure is performed through a write to the "Calibrate Procedure" register (Register 31).

When performing the calibration procedure the encoder does not distinguish between signed or unsigned positions. It is up to the master to express the calibration position in the appropriate format.

For a description of the calibration procedure, refer to Appendix C.

Range: Not defined (refer to Appendix A)
Default: 500000

Register 31 – Calibrate Procedure

A write to this register will initiate the calibration procedure regardless of the value written.

A read will always return 0 (0x0000).

For a description of the calibration procedure, refer to Appendix C.

Range: N/A
Default: N/A

Register 32 – Device Address

Device address of encoder.

Range: 1 – 247 (0x0001 – 0x00F7)
Default: 1

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Register 33 – Baud Rate

Baud rate used for communication.

Value	Baud Rate
1 (0x0001)	2400
2 (0x0002)	4800
3 (0x0003)	9600
4 (0x0004)	19200
5 (0x0005)	38400
6 (0x0006)	57600
7 (0x0007)	115200
8 (0x0008)	230400
9 (0x0009)	460800
10 (0x000A)	921600
11 (0x000B)	1843200
12 (0x000C)	3686400

Range: 1 – 12 (0x0001 – 0x000C)
Default: 4 (19200 baud)

Register 34 – Bus Termination

Enable/disable 120Ω bus termination in the encoder. Only one device on the bus may have the termination resistor enabled and this must always be the last device in the chain.

Disable = 0 (0x0000)
Enable = any value different from 0

Note - even though a write of any value different from 0 will enable the termination, a read will always return 65635 (0xFFFF) if the termination resistor is enabled.

Range: 0 – 65635 (0x0000 – 0xFFFF)
Default: 0 (disabled)

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6.0 Slave ID

In response to the "Report Slave ID" request (function code 17) the eCODE Encoder will return the following answer:

Byte no.	Name	Description
1	Address	Encoder address
2	Function Code	17 (0x11)
3	Byte Count	7 (0x07)
4	Slave ID	See description below
5	Run Indicator	255 (0xFF) – Always ON
6	Firmware Version Major	See description below
7	Firmware Version Minor	See description below
8	Options	See description below
9	Reserved	Not defined (internal use)
10	Reserved	Not defined (internal use)
11	CRC Low	Low byte of CRC
12	CRC High	High byte of CRC

Slave ID At present time the following Slave ID's are defined.
Slave ID 01 (0x01) – eCODE 2048 Series Encoder.
Slave ID 02 (0x02) – eCODE 1024 Series Encoder.
Slave ID 03 (0x03) – eCODE 512 Series Encoder.

Firmware Version The firmware version is expressed as major**.**minor where minor should be interpreted as a 2-digit value (in decimal notation). If, for example, major = 2 (0x02) and minor = 42 (0x2A) the firmware version is 2.42.

Options There are no options defined at present time. Therefore, this field will be 0.

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Appendix A

Position Value Formats

To give the greatest flexibility, the eCODE Encoders offer different views of the position.

All views are present at any time and it is therefore only necessary for the master to request for the position in the wanted format.

The following formats are supported:

1. **Signed Multiturn:** The position is returned as a signed 32 bit integer in 2-complement notation. A pass from a higher value through 0 will continue with a negative value. The position value contains contributions from both the singleturn value and the revolutions.

2. **Unsigned Multiturn:** The position is returned as an unsigned 32 bit integer. A pass from a higher value through 0 will continue with the highest position value. The position value contains contributions from both the singleturn position and the revolutions.

3. **Unsigned Revolutions/Singleturn:** The position is returned as two values where the first value is the number of revolutions and the second value is the singleturn (position within one revolution) value. The number of revolutions is returned as an unsigned 16 bit integer and the singleturn position is returned as an unsigned 32 bit integer. A pass from a higher value through 0 will continue with the highest position value for both the revolutions and the singleturn value.

4. **Unsigned Singleturn:** The position value is returned as an unsigned 32 bit integer. A pass from a higher value through 0 will continue with the highest position value. The position value contains only positions within one revolution and will therefore repeat itself for each revolution.

5. **Unsigned Revolutions:** The position value is returned as an unsigned 16 bit value. A pass from a higher value through 0 will continue with the highest position value. The position value contains only the number of full revolutions.

Care should be taken when setting parameters that are related to or that reference the position value so that these parameters are in accordance with the required position value format. Examples of such parameters include the preset of the position and values for the max. and min. limits. It is the responsibility of the master that these parameters are set correctly.

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Appendix B

Definition of Status Bits

Bit no.	Name	Description
1 (lsb)	Ready	Set: Encoder is ready. The encoder does not report reliable position data until this bit is set.
2	Position Calibrated	Set: Encoder position is calibrated This bit will be clear after a power up and be set after a successful position calibration. This can either be because of a direct position preset (see above – Sec. 5.2 Holding Registers) or because of the completion of the position calibration procedure.
3	Above Max. Limit	Set: Present position is above max. limit. This bit will be set if the present position is above the programmable maximum limit (see above – Sec. 5.2 Holding Registers).
4	Below Min. Limit	Set: Present position is below min. limit. This bit will be set if the present position is below the programmable minimum limit (see above – Sec. 5.2 Holding Registers).
5	Temperature High	Set: Encoder temperature is high. This bit is set if the temperature inside the encoder is high but still within specifications. The setting of this bit should be considered as a warning.
6	Temperature Above Limit	Set: Encoder temperature is above limit. This bit is set if the temperature inside the encoder is above specifications. If this bit is set, reliable operation of the encoder cannot be guaranteed.
7	Voltage Low	Set: Encoder supply voltage is low. This bit is set if the supply voltage of the encoder is low but still within specifications. The setting of this bit should be considered as a warning.

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8	Voltage Below Limit	Set: Encoder supply voltage is below limit. This bit is set if the supply voltage of the encoder is below specifications. If this bit is set, reliable operation of the encoder cannot be guaranteed.
9	RPM High	Set: Encoder RPM is high. This bit is set if the rotational speed of the encoder is high but still within specifications. The setting of this bit should be considered as a warning.
10	RPM Above Limit	Set: Encoder RPM is above limit. This bit is set if the rotational speed of the encoder is above specifications. If this bit is set, the encoder will not report reliable position information. If this bit is set, the "Position Calibrated" bit (bit 2) will be cleared as the correctness of the position calibration cannot be trusted.
11	Not Used	Always clear. (for future use)
12	Not Used	Always clear. (for future use)
13	Not Used	Always clear. (for future use)
14	Not Used	Always clear. (for future use)
15	Not Used	Always clear. (for future use)
16 (msb)	Fatal Error	Set: A fatal error has been detected. If this bit is set, reliable operation of the encoder cannot be guaranteed. It is advised to restart the encoder (cycle the power) and re-calibrate the encoder position.

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Appendix C

Calibration Procedure

(not implemented in firmware ver. 1.00)

Besides directly presetting the encoder, the eCODE Encoders offer assistance in calibrating the encoder to the desired position through a built-in position calibration procedure. The calibration procedure uses the encoder's internal index pulse and will therefore give the maximum accuracy and repeatability.

The steps in the calibrating procedure are as follows:

1. The Calibration Position register must contain the desired calibration value. This can either be written as a part of the calibration procedure or can be the value that was saved in the internal memory on a previous run of the calibration procedure.

2. The encoder is moved (rotated) to a position for which it is known that the next occurrence of the index pulse will arrive at the position the encoder should be pre-set to.

3. A value is written to the Calibrate Procedure register to initiate the calibration procedure. This will also clear the Calibrated bit in the status register if it is set.

4. The encoder is slowly moved (rotated). The master can, if desired, continuously read the status register. When the Calibrated bit in the status register is set or the encoder has been rotated at least one revolution the encoder position has been calibrated.

The rotational speed of the encoder during the calibration procedure must not exceed 1/10 of the Maximum Rotational Speed for the encoder series (refer to Appendix D).

Appendix D

Characteristics of the eCODE Encoder Series

The eCODE Series of Encoders consists of the eCODE 2048 Series, the eCODE 1024 Series and the eCODE 512 Series. The characteristics of the three encoder series are described below.

eCODE Series	Maximum Positions per Revolution [1]	Maximum Number of Revolutions	Maximum Rotational Speed [2]
2048	524,288 (19 bit)	8,192 (13 bit)	4,500 RPM
1024	262,144 (18 bit)	16,384 (14 bit)	9,000 RPM
512	131,072 (17 bit)	32,768 (15 bit)	18,000 RPM

[1] The values for Maximum Positions per Revolution cannot be used as Positions per Revolution with signed representation of the position. For signed representation the maximum value for Positions per Revolution is: (Maximum Positions per Revolution / 2) - 1.

[2] The values for the Maximum Rotational Speed are the theoretical maximum values. The actual maximum rotational speed for a given encoder may be lower due to mechanical limitations.

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Document Revision History

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1.0	October 16. 2009	1.00	Initial version

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