MEASURING INSTRUMENTS

Mach Smart / Smart Più / Duca47(-72/-96)-SP / Duca-LCD / Duca-LCD96

MODBUS-RTU PROTOCOL MANUAL

REVISIONS

REV.	VER	DATA	MOTIVO
2	0	17/07/98	Adding to pages 7
3	0	01/12/98	Multivariable Read
4	0	18/02/00	Errata corrige
5	0	30/05/00	New memory map function 06
6	0	20/11/00	Functions 01 06
7	0	27/11/01	New command for SMART Più
8	0	17/12/02	New ID for SMART96 Più; Voltage and Current ThdF for SMART Più and SMART96 Più. Different management of the requests with memory overflow (from V3.03)
9	0	28/11/03	New ID and Apparent energy measurement for SMART(96) Più V3.11(KVAh)
10	0	17/09/04	For SMART(96) Più from version V3.12. Update new instruments ID and new range for CT ratio
10 Bis	0	07/07/05	DUCA47(-72-96-SP) – only for model Duca47-72-SP with serial interface and pulse outputs
10 Tris	0	18/01/07	Add note for DUCA47(-72-96-SP) answer for Function 17h "Report slave ID"
11	0	18/05/14	Update for models DUCA-LCD96
12	0	05/11/14	Update for output commands with active alarms Updated ID table for introduction of the DUCA-LCD models Update memory map for introduction of harmonics and THD (DUCA-LCD models) Updated notes about binary formats used in map
13	0	01/09/17	Update for introduction of R5 / R8 commands and map
14	0	12/11/17	Update for introduction of R5/R8 floating point map
15	0	22/03/18	Errata corrige
16	0	12/01/22	Document format changed The contributions dedicated to R5 and R8 regulators have been eliminated

Contents

1. Communication frame in RTU mode (Remote Terminal Unit)

A MODBUS frame is composed of:

T1 T2 T3	Address (8 bits)	Function (8 bits)	Data (N x 8 bits)	CRC (16 bits)	T1 T2 T3

in which:

a) the Address field contains the address of the Slave to which the message is sent

b) the Function field contains the code of the function that must be carried out by the Slave

c) the Data field contains the information needed by the Slave to carry out a specific function or contains data collected from the Slave in response to a question

d) the CRC field allows both the Master and the Slave to check a message in order to detect any errors in transmission. Sometimes, due to electrical "noise" or other interference, a message may be changed during the transmission from one unit to another. The error check ensures that neither the Master nor the Slave react to messages that have been haltered

e) the T1 T2 T3 sequence represents the time that separates one frame from another, and corresponds to at least 3 and a half characters: during this period no one is allowed to talk on the bus, to let the instruments detect that a frame is over and another one is starting

In RTU mode, the synchronisation of the frame can be maintained only by simulating a synchronous message. The receiving device, a Mach SMART for example, measures the time that separates the reception of one character and the reception of the subsequent one (for example, between address and function). If this time is longer than the time needed to transmit three and a half characters, then the message is considered lost and the next character arriving is considered to be an address, in other words the beginning of a new frame.

2. Activation of MODBUS protocol and available functions

To activate the MODBUS protocol in the MACH SMART, Smarti Più and in DUCA47-72-96-SP, "**1**" must be selected in the last field of the Setup indicated by "**PROT**" (0 = DUCBUS , 1 = MODBUS). For DUCA-LCD96 and DUCA-LCD models is necessary enter the setup menu and set "Prot MODBUS" in the "Protocol" page of the Communication's menu.

The available MODBUS functions are reported in the following table:

MODBUS Functions	Action performed in the analyser
01 = READ OUTPUT STATUS	Read data relative to the output status
03 = READ HOLDING REGISTERS	Reads data relative to the Measurements and the Setup
05 = FORCE SINGLE COIL	Set the output state
06 = PRESET SINGLE REGISTER	Sets Setup parameters
07 = READ EXCEPTION STATUS	Reads Instrument status
17 = REPORT SLAVE ID	Reads the identification of the instrument type

IMPORTANT NOTE REGARDING FUNCTIONS 3 AND 6 DESCRIBED BELOW:

Whenever the user employs commercial programs for reading the data from the Slaves, and these programs are already designed for handling the MODBUS protocol, it is necessary to use the addresses of the storage locations indicated in the first left-hand column of the tables relative to functions 3 and 6 illustrated below.

Instead, whenever the user writes his own program to read the data <u>it is necessary to decrease by one the addresses reported.</u>

For example: the Master wishes to read from Mach SMART with address 3 the value of the three-phase equivalent current, available at memory address 18 (= 12Hex).

The communication frame of the Master to the Slave, with hexadecimal values, will be the following:

03	03	00	11	00	02	95	EC

where:

03 = address of Mach SMART (Slave) no. 03

03 = function requested by the Master, in this case measure reading request

00 11 = address, reduced by one unit (12H - 1H = 11H), of the storage location to be read and containing the value of the three-phase equivalent current

00 02 = number of registers to be read beginning with address 11H

95 EC = CRC

The Slave response frame to the Master in hexadecimal values will be the following:

03	03	04	00	00	01	E0	D9	EB

in which:

03 = address of Mach SMART (Slave) no. 03

03 = function requested by the Master, in this case measure reading request

04 = number of data bytes following in the frame

00 00 01 E0 = hex value of the three-phase equivalent current (01E0H = 480 hundredths of A = 4.8A)

D9 EB = CRC

2.1 Function 01 : "READ OUTPUT STATUS"

This function is used to read the status of the SMART96, SMART Più, DUCA-LCD or DUCA-LCD96 output; the output is treated like a coil, following MODBUS standard.
The request and answer frame are described below:

Read request (master):

Addr	Func	Coil Addr Start H	Coil Addr Start L	Number of Coils H	Number of Coils L	CRC	CRC
1Fh	01h	00h	00h	00h	08h	3Eh	72h

In the example above the "read output function" **Func = 01** is sent to the slave with address **Addr = 1Fh**, starting from register **Coil Addr Start = 0000h** (compulsory) for **Number of coils = 08h** (compulsory) adjacent coils. The frame is closed with **CRC=3E72h**.

Reply (slave):

Addr	Func	Byte Count	Data Coil Byte 0H	CRC	CRC
1Fh	01h	01h	00h	57h	A0h

The answer fields, as described above, are the slave address **Addr = 1Fh**, the function executed **Func = 01**, the number of data bytes following **Byte Count = 01h**, the coil value **00h.** In the SMART 96 the 5th bit is its only output, all the others are forced to 0; for the SMART Più the relevant bits are bit 0 and bit 1 (1st and 2nd bit respectively for output 1 and output 2); for models DUCA-LCD and DUCA-LCD96 are bit 0 and bit 1 (1st and 2nd bit respectively for output 1 and output 2); furthermore, only for model DUCA-LCD96 485-RELE, bit 2 and bit 3 are related respectively to output 3 and output 4. The frames ends with the CRC.

This function is available in the SMART 96 from version 1.01 onwards and for model 2P of SMART Più. For DUCA47(-72/-96)-SP the command is not operational.

2.2 Function 03 : “READ HOLDING REGISTERS”

This function reads one or more memory adjacent locations, each one being 2-word sized. It is possible to read up to 12 or 24[iii] consecutive measures[*]. Moreover SMART Più can read a Mix of measures previously configured (see 2.4).

Below are described the read request format (from master to slave) and the reply format (from slave to master).

Read request (master):

Addr	Func	Data Start Register H	Data Start Register L	Data # of Regs H	Data # Regs L	CRC	CRC
1Fh	03h	00h	11h	00h	08h	17h	B7h

In the example above, the master sends the ‘read function’ **Func = 03** to the slave with address **Addr = 1Fh**, starting from base register address **Data Start Register = 0011h** for **Data Regs = 08h** consecutive registers. So the command reads all registers from address **0011h** to **0018h**. The **CRC = 17B7h** closes the data stream.

(Note: the physical address is always obtained from measure address reduced of 1 unit, see note above).

[iii] SMART Più family, DUCA47(-72/-96)-SP, DUCA-LCD and DUCA-LCD96 family: 24 measures.

[*] Mach SMART with firmware versions earlier than 1.H07 allow only one value (2 words) per enquiry to be read.

Reply (slave):

Addr	Func	Byte count	Data Out Reg 0012 H	Data Out Reg 0012 L	……	Data Out Reg 0018H	Data Out Reg 0018L	CRC	CRC
1Fh	03h	10h	10h	EFh	……..	3Bh	40h	xxh	yyh

The table above shows the fields in the MACH SMART reply, which are :

-Addressed Slave **Addr = 1Fh**
-Function code request **Func = 03**
-Number of data byte following **Byte Count = 10h**
-Data byte fields requested by the master
-CRC closes the reply data stream

There are **three particular cases** that can happen using this command; the first is related to the quantity of requested memory, the second is related to the beginning of the requested segment and the last is related to the quantity of the requested words.
In particular, if the quantity of the requested bytes is greater than the MACH's memory extension, the instrument will answer an "INVALID DATA" for the not available values; for example, if are requested 20 byte from the last fourth valid address, a part of the request overflows in the non available memory. The exceeded bytes will be filled by the SMART with the value FFh[iv], indicating a non managed value for those memory cells.
The second particular case is related to a request starting from a non valid address, when the request starts from an address not present in the following table. In this case the instrument will answer with an exception "02 ILLEGAL DATA ADDRESS" (see chapter 3).
The last particular case is the request of a number of word greater than the maximum for the instrument: in this case the instrument will answer with an exception "02 ILLEGAL DATA address" (see chapter 3).

Memory map

The following table indicates the correspondence between the address of the location, the number of accessible words beginning with that address, the description of the measurement value, the unit of measurement of the measurement value and the binary format.

Formats of the variables passed:

- **Unsigned Long:** means a binary number of 2 words (32 bits) unsigned

- **Bit Signed Long**: means a binary number of 2 words (32 bits) if not, the MSB is set to 1. For example: 8000 0007h = -7.

- **Signed Int**: means a binary 2's-complement number

- **Unsigned Int:** is a binary number of 1-word (16-bit) unsigned

Add.	Word	Measurement description	Unit	Format
0002	2	Frequency	Tenths of Hz	Unsigned Long
0004	2	Three-phase Equivalent Voltage	V	Unsigned Long
0006	2	Line Voltage (line 1 - line 2)	V	Unsigned Long
0008	2	Line Voltage (line 2 - line 3)	V	Unsigned Long
0010	2	Line Voltage (line 3 - line 1)	V	Unsigned Long
0012	2	Voltage between Phase and Neutral line 1	V	Unsigned Long

[iv] SMARTPiù from V. 3.03 on; in the V. 3.00 the slave answer at this request was an exception 02.

0014	2	Voltage between Phase and Neutral line 2	V	Unsigned Long
0016	2	Voltage between Phase and Neutral line 3	V	Unsigned Long
0018	2	Three-phase Equivalent Current	Hundredths of A	Unsigned Long
0020	2	Current Line 1	Hundredths of A	Unsigned Long
0022	2	Current Line 2	Hundredths of A	Unsigned Long
0024	2	Current Line 3	Hundredths of A	Unsigned Long
0026	2	Three-phase equivalent power factor*	Hundredths	bit-Signed / Unsigned Long[v]
0028	2	Power factor line 1*	Hundredths	bit-Signed Long
0030	2	Power factor line 2*	Hundredths	bit-Signed Long
0032	2	Power factor line 3*	Hundredths	bit-Signed Long
0034	2	Three-phase equivalent active power	W	bit-Signed Long[vi]
0036	2	Average three-phase equivalent active power	W	bit-Signed Long[vi]
0038	2	Maximum three-phase equivalent active power	W	bit-Signed Long[vi]
0040	2	Active power line 1	W	bit-Signed Long[vi]
0042	2	Active power line 2	W	bit-Signed Long[vi]
0044	2	Active power line 3	W	bit-Signed Long[vi]
0046	2	Average active power line 1	W	bit-Signed Long[vi]
0048	2	Average active power line 2	W	bit-Signed Long[vi]
0050	2	Average active power line 3	W	bit-Signed Long[vi]
0052	2	Maximum active power line 1	W	bit-Signed Long[vi]
0054	2	Maximum active power line 2	W	bit-Signed Long[vi]
0056	2	Maximum active power line 3	W	bit-Signed Long[vi]
0058	2	Three-phase equivalent apparent power	VA	bit-Signed Long
0060	2	Average three-phase equivalent apparent power	VA	Unsigned Long
0062	2	Maximum three-phase equivalent apparent power	VA	Unsigned Long
0064	2	Apparent power line 1	VA	Unsigned Long
0066	2	Apparent power line 2	VA	Unsigned Long
0068	2	Apparent power line 3	VA	Unsigned Long
0070	2	Average apparent power line 1	VA	Unsigned Long
0072	2	Average apparent power line 2	VA	Unsigned Long
0074	2	Average apparent power line 3	VA	Unsigned Long
0076	2	Maximum apparent power line 1	VA	Unsigned Long
0078	2	Maximum apparent power line 2	VA	Unsigned Long
0080	2	Maximum apparent power line 3	VA	Unsigned Long
0082	2	Three-phase equivalent reactive power	VAr	bit-Signed Long[vii]
0084	2	Average three-phase equivalent reactive power	VAr	bit-Signed Long[vii]

[v] For SMART Più, DUCA47(-72/-96)-SP, DUCA-LCD and DUCA-LCD96 this value is a bit-Signed Long.

[vi] For models DUCA-LCD and DUCA-LCD96 the values of Active Power could be negatives in Cogeneration.

[vii] For models DUCA-LCD and DUCA-LCD96 the values of Reactive Power could be negative (positive if inductive, negative if capacitive).

0086	2	Maximum three-phase equivalent reactive power	VAr	bit-Signed Long[vii]
0088	2	Reactive power line 1	VAr	bit-Signed Long[vii]
0090	2	Reactive power line 2	VAr	bit-Signed Long[vii]
0092	2	Reactive power line 3	VAr	bit-Signed Long[vii]
0094	2	Average reactive power line 1	VAr	bit-Signed Long[vii]
0096	2	Average reactive power line 2	VAr	bit-Signed Long[vii]
0098	2	Average reactive power line 3	VAr	bit-Signed Long[vii]
0100	2	Maximum reactive power line 1	VAr	bit-Signed Long[vii]
0102	2	Maximum reactive power line 2	VAr	bit-Signed Long[vii]
0104	2	Maximum reactive power line 3	VAr	bit-Signed Long[vii]
0106	2	Three-phase equivalent active energy	Tens of Wh	Unsigned Long
0108	2	Active energy line 1	Tens of Wh	Unsigned Long
0110	2	Active energy line 2	Tens of Wh	Unsigned Long
0112	2	Active energy line 3	Tens of Wh	Unsigned Long
0114	2	Three-phase equivalent reactive/apparent energy [viii]	Tens of VArh/VAh	Unsigned Long
0116	2	Reactive/Apparent energy line 1 [viii]	Tens of VArh/VAh	Unsigned Long
0118	2	Reactive/Apparent energy line 2 [viii]	Tens of VArh/VAh	Unsigned Long
0120	2	Reactive/Apparent energy line 3 [viii]	Tens of VArh/VAh	Unsigned Long
0122	2	Max. average three-phase active power	W	bit-Signed Long[vi]
0124	2	Line 1 normal format voltage ThdF (only for DUCA-LCD96 and DUCA-LCD; for SMART Più and SMART96 Più from revision V. 3.10)[&]	Hundredths	Unsigned Long
0126	2	Line 2 normal format voltage ThdF (only for DUCA-LCD96 and DUCA-LCD)[&]	Hundredths	Unsigned Long
0128	2	Line 3 normal format voltage ThdF (only for DUCA-LCD96 and DUCA-LCD)[&]	Hundredths	Unsigned Long
0130	2	Line 1 normal format current ThdF (only for DUCA-LCD96 and DUCA-LCD; for SMART Più and SMART96 Più from	Hundredths	Unsigned Long

[viii] The DUCA-LCD96, DUCA-LCD and DUCA47(-72/-96)-SP return always the Reactive Energy; the SMART Più and the SMART96 Più, version 3.11 or later, return the Apparent Energy when the CFG parameter is set to 28, 33 or 38, otherwise the Reactive Energy. Not valid for other instruments.

		revision V. 3.10)&		
0132	2	Line 2 normal format current ThdF (only for DUCA-LCD96 and DUCA-LCD)&	Hundredths	Unsigned Long
0134	2	Line 3 normal format current ThdF (only for DUCA-LCD96 and DUCA-LCD)&	Hundredths	Unsigned Long
0136	2	Maximum Average Active Power line 1 (only for DUCA-LCD96 and DUCA-LCD)	W	bit-Signed Long
0138	2	Maximum Average Active Power line 2 (only for DUCA-LCD96 and DUCA-LCD)	W	bit-Signed Long
0140	2	Maximum Average Active Power line 3 (only for DUCA-LCD96 and DUCA-LCD)	W	bit-Signed Long
0142	2	Max. average three-phase Apparent Power (only for DUCA-LCD96 and DUCA-LCD)	VA	Unsigned Long
0144	2	Maximum Average Apparent Power line 1 (only for DUCA-LCD96 and DUCA-LCD)	VA	Unsigned Long
0146	2	Maximum Average Apparent Power line 2 (only for DUCA-LCD96 and DUCA-LCD)	VA	Unsigned Long
0148	2	Maximum Average Apparent Power line 3 (only for DUCA-LCD96 and DUCA-LCD)	VA	Unsigned Long
0150	2	KV constant$ (VT transformation ratio)	Unit	Unsigned Long
0152	2	KA constant$ (CT transformation ratio)	Unit	Unsigned Long
0154	2	Time of Average	Minute	Unsigned Long
0156	2	Average Active Power from pulses input (CH1) – only for DUCA-LCD and DUCA-LCD96 485-IO	W	Unsigned Long
0158	2	Average Reactive Power from pulses input (CH2) – only for DUCA-LCD and DUCA-LCD96 485-IO	VAr	Unsigned Long
0160	2	Active Energy from pulses input (CH1) – only for DUCA-LCD and DUCA-LCD96 485-IO	Tens of Wh	Unsigned Long
0162	2	Reactive Energy from pulses input (CH2) – only for DUCA-LCD and DUCA-LCD96 485-IO	Tens of VArh	Unsigned Long
164	2	Current threshold for timer 2 activation (only for DUCA-LCD and DUCA-LCD96). Note: the read value does not include the value of KA	Hundredths of A	Unsigned Long
0166	2	Three-phase equivalent Apparent Energy	Tens of VAh	Unsigned Long

		(only for DUCA-LCD and DUCA-LCD96)		
0168	2	Apparent Energy line 1 (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0170	2	Apparent Energy line 2 (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0172	2	Apparent Energy line 3 (only for DUCA-LCD96)	Tens of VAh	Unsigned Long
0174	2	Generated Three-phase equivalent Active Energy (only for DUCA-LCD and DUCA-LCD96)	Tens of Wh	Unsigned Long
0176	2	Generated Active Energy line 1 (only for DUCA-LCD and DUCA-LCD96)	Tens of Wh	Unsigned Long
0178	2	Generated Active Energy line 2 (only for DUCA-LCD and DUCA-LCD96)	Tens of Wh	Unsigned Long
0180	2	Generated Active Energy line 3 (only for DUCA-LCD and DUCA-LCD96)	Tens of Wh	Unsigned Long
0182	2	Generated Three-phase equivalent Reactive Energy (only for DUCA-LCD and DUCA-LCD96)	Tens of VArh	Unsigned Long
0184	2	Generated Reactive Energy line 1 (only for DUCA-LCD and DUCA-LCD96)	Tens of VArh	Unsigned Long
0186	2	Generated Reactive Energy line 2 (only for DUCA-LCD and DUCA-LCD96)	Tens of VArh	Unsigned Long
0188	2	Generated Reactive Energy line 3 (only for DUCA-LCD and DUCA-LCD96)	Tens of VArh	Unsigned Long
0190	2	Generated Three-phase equivalent Apparent Energy (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0192	2	Generated Apparent Energy line 1 (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0194	2	Generated Apparent Energy line 2 (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0196	2	Generated Apparent Energy line 3 (only for DUCA-LCD and DUCA-LCD96)	Tens of VAh	Unsigned Long
0198	2	*Not used*	-	-
0200	2	1st measure configured for the Mix+	Depend	Long
0202	2	2nd measure configured for the Mix+	Depend	Long
0204	2	3rd measure configured for the Mix+	Depend	Long
0206	2	4th measure configured for the Mix+	Depend	Long
0208	2	5th measure configured for the Mix+	Depend	Long
0210	2	6th measure configured for the Mix+	Depend	Long
0212	2	Total Harmonic Distortion (THDI1) current line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long
0214	2	Total Harmonic Distortion (THDI2) current line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long
0216	2	Total Harmonic Distortion (THDI3) current line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long

0218	2	Total Harmonic Distortion (THDV1) voltage line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long
0220	2	Total Harmonic Distortion (THDV2) voltage line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long
0222	2	Total Harmonic Distortion (THDV3) voltage line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Long
224 … 999		Not used	-	-
1000	1	Harmonic module H0 current line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1001	1	Harmonic Module H1 current line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1002 … 1030		Harmonic Module Hn current line 1 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1031	1	Harmonic module H31 current line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1032 … 1099		*Not used*		
1100	1	Harmonic module H0 voltage line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1101	1	Harmonic Module H1 voltage line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1102 … 1130		Harmonic Module Hn voltage line 1 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1131	1	Harmonic module H31 voltage line 1 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1132 … 1199		*Not used*		
1200	1	Harmonic module H0 current line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1201	1	Harmonic Module H1 current line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1202 … 1230		Harmonic Module Hn current line 2 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1231	1	Harmonic module H31 current line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1232 … 1299		*Not used*		
1300	1	Harmonic module H0 voltage line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int

1301	1	Harmonic Module H1 voltage line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1302 … 1330		Harmonic Module Hn voltage line 2 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1331	1	Harmonic module H31 voltage line 2 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1332 … 1399		*Not used*		
1400	1	Harmonic module H0 current line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1401	1	Harmonic Module H1 current line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1402 … 1430		Harmonic Module Hn current line 3 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1431	1	Harmonic module H31 current line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1432 … 1499		*Not used*	‰ (thousandths of fundamental harmonic)	Unsigned Int
1500	1	Harmonic module H0 voltage line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1501	1	Harmonic Module H1 voltage line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1502 … 1530	…	Harmonic Module Hn voltage line 3 (only for Duca-LCD)$^{\beta}$	‰ (thousandths of fundamental harmonic)	Unsigned Int
1531	1	Harmonic module H31 voltage line 3 (only for Duca-LCD)	‰ (thousandths of fundamental harmonic)	Unsigned Int
1532 … 1599		*Not used*	-	-
1600	2	αi_1 factor for harmonic module conversion current line 1 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
1602	2	αv_1 factor for harmonic module conversion voltage line 1 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
1604	1	Real part Harmonic H1 current line 1 (only for Duca-LCD)	-	Signed Int
1605	1	Imaginary part Harmonic H1 current line 1 (only for Duca-LCD)	-	Signed Int
1606	1	Real part Harmonic H1 voltage line 1 (only for Duca-LCD)	-	Signed Int
1607	1	Imaginary part Harmonic H1 voltage line 1 (only for Duca-LCD)	-	Signed Int
1608 …		Real and Imaginary parts Harmonic Hn current and voltage line1 (only for Duca-	-	Signed Int

1723		LCD) $^{\beta}$		
1724	1	Real part Harmonic H31 current line 1 (only for Duca-LCD)	-	Signed Int
1725	1	Imaginary part Harmonic H31 current line 1 (only for Duca-LCD)	-	Signed Int
1726	1	Real part Harmonic H31 voltage line 1 (only for Duca-LCD)	-	Signed Int
1727	1	Imaginary part Harmonic H31 voltage line 1 (only for Duca-LCD)	-	Signed Int
1727 … 1799		*Not used*		
1800	2	αi_2 factor for harmonic module conversion current line 2 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
1802	2	αv_2 factor for harmonic module conversion voltage line 2 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
1804	1	Real part Harmonic H1 current line 2 (only for Duca-LCD)	-	Signed Int
1805	1	Imaginary part Harmonic H1 current line 2 (only for Duca-LCD)	-	Signed Int
1806	1	Real part Harmonic H1 voltage line 2 (only for Duca-LCD)	-	Signed Int
1807	1	Imaginary part Harmonic H1 voltage line 2 (only for Duca-LCD)	-	Signed Int
1808 … 1923		Real and Imaginary parts Harmonic Hn current and voltage line2 (only for Duca-LCD) $^{\beta}$	-	Signed Int
1924	1	Real part Harmonic H31 current line 2 (only for Duca-LCD)	-	Signed Int
1925	1	Imaginary part Harmonic H31 current line 2 (only for Duca-LCD)	-	Signed Int
1926	1	Real part Harmonic H31 voltage line 2 (only for Duca-LCD)	-	Signed Int
1927	1	Imaginary part Harmonic H31 voltage line 2 (only for Duca-LCD)	-	Signed Int
1927 … 1999		*Not used*		
2000	2	αi_3 factor for harmonic module conversion current line 3 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
2002	2	αv_3 factor for harmonic module conversion voltage line 3 $^{(£)}$(only for Duca-LCD)	-	Unsigned Long
2004	1	Real part Harmonic H1 current line 3 (only for Duca-LCD)	-	Signed Int
2005	1	Imaginary part Harmonic H1 current line 3 (only for Duca-LCD)	-	Signed Int
2006	1	Real part Harmonic H1 voltage line 3 (only for Duca-LCD)	-	Signed Int
2007	1	Imaginary part Harmonic H1 voltage line 3 (only for Duca-LCD)	-	Signed Int

2008 … 2123		Real and Imaginary parts Harmonic Hn current and voltage line 3 (only for Duca-LCD) $^{\beta}$	-	Signed Int
2124	1	Real part Harmonic H31 current line 3 (only for Duca-LCD)	-	Signed Int
2125	1	Imaginary part Harmonic H31 current line 3 (only for Duca-LCD)	-	Signed Int
2126	1	Real part Harmonic H31 voltage line 3 (only for Duca-LCD)	-	Signed Int
2127	1	Imaginary part Harmonic H31 voltage line 3 (only for Duca-LCD)	-	Signed Int

(*) Regarding the **power factor**, please note that:

- power factor of the three lines may be negative; the instruments report negative numbers with the most significant bit (the 32nd) high (1) in case of negative Power Factor (capacitive), while positive numbers have the same bit low (0) in case of positive Power Factor (inductive).
- when the power factor for a line is undefined (current is zero), the instruments return the value "2" (200 cents) to report about this situation

(+) For the **Mix of measure** pay attention to the follows:

- it is available only for SMART Più / SMART96 Più release V. 3.03 or later. This feature is not present in the other instruments
- if not set or after a global reset, the measures are set to the first 6 measures of the list (frequency, three-phase equivalent voltage...)

(&) For the voltage and current **ThdF** pay attention to the followings:

- the ThdF represents the normalised voltage and current crest factor
- it is available only for SMART Più and SMART 96 Più from revision V. 3.10 and for DUCA-LCD96
- if the instruments SMART Più or SMART96 Più are configured with PAR function, they respond to the measure's request in the same way as the measure didn't exist
- the memories 126, 128 and 132, 134 are reserved for line 2 and line 3 ThdF and are significant only for the model DUCA-LCD96, since the SMART Più and SMART 96 Più measure the ThdF only from the line 1
- even if the instrument is set to display the ThdF % (percentage format), when the memory values corresponding to the addresses from 124 to 134 are requested, it answers always with the corresponding ThdF in normal format
- in case the ThdF isn't computable (e.g. when current = 0), the instrument provides two words equal to FFFFh, corresponding to an INVALID DATA

($) For DUCA-LCD and DUCA-LCD96 the reading of **KA or KV** returns the ratio, set in the instrument, between the current (voltage) of primary and the current (voltage) of secondary. For example, if in the setup menu was set for the CT ratio the value 100/5, then the MODBUS command returns 20.

(β) Calulation of the harmonic registers addresses

Formula for calculation of register address of Harmonic Module n-th of current line k

$ADDR(Hi_{kn}) = 1000 + 100*(k-1) + n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

Formula for calculation of address register of Harmonic Module n-th of voltage line k

$ADDR(Hv_{kn}) = 1300 + 100*(k-1) + n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

Formula for calculation of register address of Real and Imaginary parts of n-th Harmonic of current line k

$ADDR[\mathrm{Re}(Hi_{kn})] = 1604 + 200*(k-1) + 4*n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

$ADDR[\mathrm{Im}(Hi_{kn})] = 1605 + 200*(k-1) + 4*n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

Formula for calculation of register address of Real and Imaginary parts of n-th Harmonic of voltage line k

$ADDR[\mathrm{Re}(Hv_{kn})] = 1606 + 200*(k-1) + 4*n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

$ADDR[\mathrm{Im}(Hv_{kn})] = 1607 + 200*(k-1) + 4*n$ $\quad n = 0, \ldots, 31$ e $k = 1, 2, 3$

Example of reading a block of 6 Mixed measure:

Addr	Func	Start Register H	Start Register L	Num. Data H	Num. Data L	CRC	CRC
1Fh	03h	00h	C7h	00h	0Ch	F7h	8Ch

In the example it set a reading of 12 bytes from index 200 (minus 1 therefore 199).

Note: "**INVALID DATA**" is shown = FFFFh.

Example of reading an Harmonic value:

Addr	Func	Start Register H	Start Register L	Num. Data H	Num. Data L	CRC	CRC
1Fh	03h	04h	BCh	00h	02h	07h	61h

In the example it set a reading of 7^{th} Harmonic module of current line 2: reading of 2 bytes starting from address1213 (minus 1 therefore 1212)

Notes:

"**INVALID DATA**" for Harmonic modules and THD values is shown = FFFFh.

"**INVALID DATA**" for Real and Imaginary parts is shown = 7FFFh.

If the fundamental frequency measured by the instrument is different from 50Hz or 60Hz or if the Line-neutral voltages and line currents are less than 20VRMS and 0,3ARMS the values of THD, Harmonic modules and Real / Imaginary parts will be INVALID

(£) **Factor for harmonic module conversion**

In order to calculate the absolute values of harmonic modules of current and voltage (expressed in A and V) use the following formula including the conversion factor αi e αv (one for each phase):

$$|Hi_{kn}| = \frac{\sqrt{\left(\mathrm{Re}\, i_{kn}{}^2 + \mathrm{Im}\, i_{kn}{}^2\right)} * \alpha i_k}{\sqrt{2} * 2^8 * 10^5} \text{ [A]} \qquad n = 2, \ldots, 31 \text{ and } k = 1, 2, 3$$

$|Hi_{kn}|$ = module of n-th harmonic of current line k
Re i_{kn} = Real part of n-th harmonic of current line k
Im i_{kn} = Imaginary part of n-th harmonic of current line k
αi_k = conversion factor of current line k

$$|Hv_{kn}| = \frac{\sqrt{\left(\mathrm{Re}\, v_{kn}{}^2 + \mathrm{Im}\, v_{kn}{}^2\right)} * \alpha v_k}{\sqrt{2} * 2^8 * 10^3} \text{ [V]} \qquad n = 2, \ldots, 31 \text{ and } k = 1, 2, 3$$

$|Hv_{kn}|$ = module of n-th harmonic of voltage line k
Re v_{kn} = Real part of n-th harmonic of voltage line k
Im v_{kn} = Imaginary part of n-th harmonic of voltage line k
αv_k = convertion factor of voltage line k

Harmonic modules expressed in thousandths of the fundamental harmonic:

$$Hi_{kn}(‰) = \frac{|Hi_{kn}|}{|Hi_{k1}|} * 1000 \qquad n = 2, \ldots, 31 \text{ and } k = 1, 2, 3$$

$$Hv_{kn}(‰) = \frac{|Hv_{kn}|}{|Hv_{k1}|} * 1000 \qquad n = 2, \ldots, 31 \text{ and } k = 1, 2, 3$$

Total Harmonic Distortion values expressed in thousandths of the fundamental harmonic:

$$THDI_k(‰) = \frac{\sqrt{\sum_{n=2}^{N} |Hi_{kn}|^2}}{|Hi_{k1}|} * 1000 \qquad k = 1, 2, 3 \text{ and } N = 21 \text{ o } 31 \text{ (see Note1)}$$

$$THDV_k(‰) = \frac{\sqrt{\sum_{n=2}^{N} |Hv_{kn}|^2}}{|Hv_{k1}|} * 1000 \qquad k = 1, 2, 3 \text{ and } N = 21 \text{ o } 31 \text{ (see Note1)}$$

Note1: in the Setup menu of the instrument is possibile to set the total number of harmonics through which are calculated THD values

2.3 Function 05 : "FORCE SINGLE COIL"

Using this function it is possible to set the status of the DUCA-LCD, DUCA-LCD96, SMART96 and SMART Più outputs; the output is treated like a MODBUS coil.

The value for "*Coil number*" is the number of correspondent Output minus 1 (n-1), therefore for DUCA-LCD96 and SMART Più outputs 1 or 2 are respectively 00h and 01h; for SMART 96 output 5 is 04h; only for DUCA-LCD96 485-RELE outputs 3 or 4 are respectively 02h and 03h.

The query and answer frames are described below.

Write request (master):

Addr	Func	Coil Num. H	Coil Num. L	Coil Status H	Coil Status L	CRC	CRC
1Fh	05h	00h	04h	FFh	00h	CEh	45h

In the example above the master forces the output of a Smart96 (output n.5) to 1: the "force single coil" **Func = 05** is sent to the slave with address **Addr = 1Fh**, followed by **Coil Number = 00 04h** (n-1). The **Coil Status** value must be one of the following:

- to set the output: **FF 00h**
- to reset the output: **00 00h**

The CRC **CE45h** ends the frame.

Reply (slave):

Addr	Func	Coil Num. H	Coil Num. L	Coil Status H	Coil Status L	CRC	CRC
1Fh	05h	00h	04h	FFh	00h	CEh	45h

If the query is correct, the query frame itself is sent back from the slave to the master, otherwise the exception is reported in the second byte (which becomes **85h**).

This function is available in the SMART 96 from version 1.01 onwards, in the SMART Più model "2P" and in the instruments DUCA-LCD and DUCA-LCD96.

Note: if the alarm is active, is not possibile to reset the output; however the slave replies with a confirmation frame; if the pulse option is set (or if the slave model has no outputs) the slave replies with an exception frame.

2.4 Function 06 : "PRESET SINGLE REGISTER"

This function lets the user set the Setup parameters of the instrument.

Addr.	Words	Parameter description	Min.	Max.	Format
0002	1	V.T. Ratio	1	500 [ix]	Unsigned int
0004	1	C.T. Ratio	1	1250 [x]	
0006	1	Average period	1	60	Unsigned int
0008	1	MACH reset, may be one of the following: [xi] ***a)*** the value "5" resets the average and max. powers ***b)*** the value "10" resets average powers, max. powers and energies	-	-	Unsigned int
0014	1	MACH address	1	247	Unsigned int
0016	1	Enables (if value=0) or disables (if value=1) the setup menu[xii]	-	-	Unsigned int
0018	1	Index 1st value for Mix of measure [xiii]	0002	0154	Unsigned int
0020	1	Index 2nd value for Mix of measure [xiii]	0002	0154	Unsigned int
0022	1	Index 3rd value for Mix of measure [xiii]	0002	0154	Unsigned int
0024	1	Index 4th value for Mix of measure [xiii]	0002	0154	Unsigned int
0026	1	Index 5th value for Mix of measure [xiii]	0002	0154	Unsigned int
0028	1	Index 6th value for Mix of measure [xiii]	0002	0154	Unsigned int
0150	1	V.T. Ratio	1	500 [ix]	Unsigned int
0152	1	C.T. Ratio	1	1250 [x]	Unsigned int
0154	1	Average period	1	60	Unsigned int

Please note that the write addresses 150, 152 and 154 are just a copy of the addresses 2, 4, 6 in this order, and that there is no difference between the "low" address and "high" address. The high addresses are available for SMART96 version 1.0 onwards, Mach SMART version 1.11 onwards, SMART Più, DUCA47, DUCA-LCD and DUCA-LCD96.

In SMART(96)Più a variable table of up to 6 measures can be can be configured. So with one reading the instruments sends the six measures of a pre-set Mix of value (index 18 - 28).

Frame format:

Addr	Func 06	Register H	Register L	DATA H	DATA L	CRC	CRC

Example 1:

[ix] 400 for MACH SMART. For DUCA-LCD and DUCA-LCD96 the maximum selectable value is 600 and the command sets in the instrument the value of VT's secondary voltage to 100V and the value of VT's primary voltage to VT*100V.

[x] SMART Più from version V3.12. In the previous versions and for other instruments the maximum value for CT ratio was 1000. For DUCA-LCD and DUCA-LCD96 the maximum selectable value is 2000 and the command sets in the instrument the value of CT's secondary current to 5A and the value of CT's primary voltage to CT*5A.

[xi] The reset 15 in not available since the default setting will set the instrument into "*DUCATI protocol*" and so the instrument would not be reachable any more by Modbus.

[xii] Not for DUCA47, DUCA-LCD and for DUCA-LCD96

[xiii] This value are available only for SMART Più. If not set or after a global reset, this measure are set to the first six measure of the list (frequency, three-phase equivalent voltage...).

Addr	Func	Register H	Register L	DATA H	DATA L	CRC	CRC
1Fh	06h	00h	11h	00h	6Ah	5Ah	5Eh

In the last example the first index(0018) of Mix is set to three-phase active energy (0106).

Notes:

The index must be the real index minus 1 (0018-1 = 0017), while the value of the measure's index must be the actual one (0106).

Example 2:

Addr	Func	Register H	Register L	DATA H	DATA L	CRC	CRC
1Fh	06h	00h	0Fh	00h	01h	7Bh	B7h

In the example the instrument at address 31 receive a keyboard lock (data = 0001) by function 06 at address 0016 (minus 1 = 0015).

2.5 Function 07 : "READ EXCEPTION STATUS"

This function makes it possible to read the status of the instrument. It gives a byte in which each bit (when equal to 1) has the following meaning:

Bit	Meaning
0	Indicates that the instrument has undergone at least one HW Reset since the last reading of that register
1	Not used
2	Not used
3	Not used
4	Not used
5	Not used
6	Not used
7	Indicates that the instrument has the Setup menu active

2.6 Function 17 : "REPORT SLAVE ID"

This function makes it possible to read the instrument identifier.

Read request (master):

Addr	Func	CRC	CRC
02h	11h	C0h	DCh

In this example the id request is sent using **Func = 11h** to the slave with address **Addr = 02h**, the CRC **C0DCh** ends the frame.

Reply (slave) – case 1:

Addr	Func	Len	Inst. type	///	///	Fw rel.	CRC	CRC
02h	11h	04h	09h	FFh	00h	C8h	F8h	7Bh

The answer contains address and function, the number of data bytes **Len = 04h**, the analyser description **Inst. type = 09h**, and the firmware version **Fw rel. = C8h (200)**: this value must be divided by 100 (V2.00). CRC **F87Bh** ends the frame.

For version 2.56 onwards the field **Fw rel.** is filled with 00 and the two fields that were previously unused, are filled with the hex value of release:

Reply (slave) – case 2:

Addr	Func	Len	Inst. type	Fw rel. H	Fw rel. L	///	CRC	CRC
02h	11h	04h	15h	01h	2Ch	00h	h	h

In the example:

Fw rel. 012Ch = V 3.00

NOTE: DUCA47 with serial interface and pulse outputs (Identifier = 80), DUCA-LCD and DUCA-LCD96 answer always like **case 2**, even if the Firmware Release is lower than 2.55.

Identifier	Analyser model
09	MachSMART three-phase (5A)
10	MachSMART three-phase (50A)
11	MachSMART Dark three-phase (5A)
12	MachSMART Dark three-phase (50A)
13	MachSMART single phase (5A)
14	MachSMART single phase (50A)
15	SMART 96
16	MachSMART Dark single phase (230/240Vac - 5A)
20	SMART Più 5A
21	SMART Più 5A with 2 output as pulse or alarms (models 2P)
22	SMART Più 5A (KVAh) [xiv]
23	SMART Più 5A (KVAh) [xiv] with 2 output as pulse or alarms (models 2P)
25	SMART 96 Più 5A
26	SMART 96 Più 5A with 2 output as pulse or alarms (models 2P)
27	SMART 96 Più 5A (KVAh) [xiv]
28	SMART 96 Più 5A (KVAh) [xiv] with 2 output as pulse or alarms (models 2P)
29	SMART Più 1A
30	SMART Più 1A with 2 output as pulse or alarms (models 2P)
31	SMART Più 50A
32	SMART Più 50A with 2 output as pulse or alarms (models 2P)
33	SMART96 Più 1A
34	SMART96 Più 1A with 2 output as pulse or alarms (models 2P)
35	SMART96 Più 50A
36	SMART96 Più 50A with 2 output as pulse or alarms (models 2P)
55	DUCA-LCD96 BASE-485
57	DUCA-LCD96 485
58	DUCA-LCD96 485-RELE

[xiv] You will obtain this ID from SMART Più and SMART 96 Più, Ver 3.11 or later, if you set CFG parameter to value 28, 33 or 38. See the instrument's manuals for more information.

59	DUCA-LCD96 485-IO
60	SMART Più 1A KVAh[xiv]
61	SMART Più 1A KVAh[xiv] with 2 output as pulse or alarms (models 2P)
62	SMART Più 50A KVAh[xiv]
63	SMART Più 50A KVAh[xiv] with 2 output as pulse or alarms (models 2P)
64	SMART96 Più 1A KVAh[xiv]
65	SMART96 Più 1A KVAh[xiv] with 2 output as pulse or alarms (models 2P)
66	SMART96 Più 50A KVAh[xiv]
67	SMART96 Più 50A KVAh[xiv] with 2 output as pulse or alarms (models 2P)
76	DUCA-LCD 485
77	DUCA-LCD 485-ETH
80	DUCA47 with Serial line and pulse outputs

3. Exceptions on the Bus

Below is a table of the exceptions handled for errors regarding access to the bus.

Exception	Description
01 ILLEGAL FUNCTION	An unsupported function code has been sent
02 ILLEGAL DATA ADDRESS	Illegal address
03 ILLEGAL DATA VALUE	A setup datum is outside of the acceptable limits

4. CRC algorithm

The CRC used in MODBUS follows the standard CRC-16 defined by CCITT. Many algorithms are ready off-the-shelf, below one is reported, written in C, which uses a look-up table.

```
/*     CRC-16 (reverse) table lookup for Modbus CRC-16
 *       Project:  Modbus
 *       Author:   Lynn August Linse, based on method used by XMODEM
 * 16Feb94 LAL Create from book about XMODEM
*/
word crc16_rev_table[256] =
{      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};

unsigned fast_crc16( unsigned char *ucpBuf, int nSize){
      register word x;
      register word crc;

      int i;
      crc = 0xFFFF;       /* start with all 1's for a reverse CRC */

      for( i = 0; i < nSize; ++i) {
            /* process each character in the message - 2 steps per char only! */
            x = crc ^ ucpBuf[i];
            crc = (crc >> 8) ^ crc16_rev_table[x & 0x00FF];
      }
      return( crc);
}
```