AR3DC

TECHNICAL DESCRIPTION, COMMUNICATIONS PROTOCOL, AND OPERATING INSTRUCTIONS

1. **INDEX**.

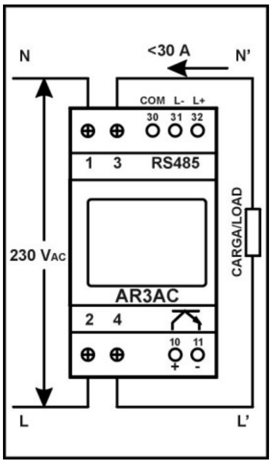
1.- GENERAL DESCRIPTION.

The AR3DC unit is a complete meter housed in a modular box of 3 DIN distances with a width of 52mm. It receives voltage and current signals from a single-phase power line, measures the primary variables and calculates the rest of the variables in digital form. It is equipped with a liquid crystal display on which the instantaneous variables of the line and the energy meters are shown in pages. In addition, a serial communications line allows all the network variables to be sent to a central computer or any other data reception equipment. It also has an optical digital output that enables the signalling of alarms, or the sending of pulses corresponding to energy consumption.

The design is based on an 8-bit microprocessor, which includes a 10-bit A/D converter. This allows for high accuracy, great versatility in programming, high communication flexibility, and low power consumption, which makes its small size possible.

Special care has been taken in the design, not only in terms of accuracy, but also in terms of reliability, safety, and electromagnetic compatibility, with a view to its use in industrial environments.

It is mounted on a standard DIN rail, and all connections are made by means of solder terminals on the circuit board. Its small dimensions make it particularly suitable for switchboards with space problems. Its external appearance is shown below.



2.- TECHNICAL DESCRIPTION.

2.1.- MEASUREMENT METHOD.
The measurement is carried out completely digitally. The current transformers and voltage dividers adapt the mains signals to the levels required for conversion by the A/D converter. The microprocessor controls the sampling, following the mains frequency so that 32 samples of each of the signals are obtained per period. The samples are stored, and at the end of the period it is calculated as follows:

$Vi = sqr(\Sigma Vij^2 / 32)$ $Ii = sqr(\Sigma Iij^2 / 32)$ $Pi = \Sigma (Vij * Iij) / 32$

This gives the rms voltage and current values as well as the active power values.

VARIABLE	Total
Phase voltage	V
Line current	I
Active power	P
Active power (pos.)	Ep+
Active power (neg.)	Ep-
Energy Ah+	Ah(+)
Energy Ah-	Ah(-)

2.2.- BLOCK DIAGRAM.

A simplified block diagram is shown in the figure.

2.2.1.- Voltage and Current Measurement

Voltage is measured by means of an internal resistive divider.

Current is measured using an internal shunt for currents less than or equal to 40 A and for higher currents an external shunt with 60 mV generation is required.

The connection used is positive to earth, which means that the consumption is measured on the negative supply line.

2.2.2.- Multiplexer and A/D converter.
A 10-bit converter included in the microprocessor is used to digitise the voltage and current signals.

2.2.3.- Microprocessor.

The MICROCHIP MCP18F4520 is used. It is an 8-bit device, which includes Flash program memory, EEPROM memory for adjustments, serial port, 10-bit A/D converter and timers.

2.2.4 - EEPROM.
Configuration data, such as the definition of primary values, identity, etc., is stored in an EEPROM memory that is available inside the microcontroller.

2.2.5 - WDT.
A watchdog is used to reset the operation of the micro in case of strong electrical disturbance.

2.2.6 - SERIAL OUTPUT.

It is also available in RS485 type. The communications line is isolated from the measuring circuits by means of optical couplers. In this way, the line can be left floating, and can be connected to ground if desired, at the ideal point. The baud rate is fixed at 9600 Bps. The RS485 line must be connected to two wires. The physical connection is made by means of a fixed connector mounted on the circuit board.

2.2.7.- DIGITAL OUTPUTS.
A digital output consisting of an optical coupler is provided in the equipment. The operating mode is programmable as:
A.- Power pulse.
B.- Alarm.
C.- General purpose outputs governed by the central computer.

2.2.8.- POWER SUPPLY.
The equipment is powered directly from the measurement voltage.

2.3.- APPLICABLE STANDARDS.
The equipment has been designed and tested in accordance with the standards required for use in low voltage, industrial environments. In particular, they comply with the corresponding sections of the following standards.
IEC 255-4 Insulation tests.
CEI 801 High frequency disturbances.
EN 60068 Environmental and vibration tests.
EN 61000 EMC disturbances. Generic standards.
EN 61010 Safety of electrical equipment.
EN 61036 Class 1 active energy meters.
EN 60259 Types of enclosure protection.
EN 50081 Emission.
EN 50082 Immunity.
DIN 43864 Pulse interface.
UL 94 Flammability of plastic materials.

2.4.- CLASS OF MEASUREMENTS.
2.4.1.- Direct magnitudes: V, I, W 1
2.4.2.- Energies: kWh 1
Ah 1
2.4.3.- Reference conditions.
The operating conditions for which the specified class is applied are:

Supply voltage: Nominal
Temperature: 23º C.
Heating time: 15 minutes.
The EN61036 standard is applied for energy measurement.

2.4.4.- Measurement ranges.

Magnitude	Margin	Class
Voltage	10-120%	1
Current	4-120%	1
Active power	10-150%	1
Active energy	1-150%	1
Energy Ah	1-150%	1

2.2.5 – INSULATION CHARACTERISTICS.
Degree of insulation: Simple.
Installation category: II.
Pollution degree: 2.
Rated values: Voltage, 500V (350 V to earth).
Current, 300V.
Output, 50V.
Serial line, 50V.
Digital outputs, 500V.

- Dielectric test voltages (kV).

(* Applicable to current-insulated version only)

	Current	Voltage	Vaux	Serial output	Digital output
Current	-	-	-	2.5	2.5
Voltage	-	-	-	2.5	2.5
V aux	-	-	-	2.5	2.5
Serial output	-	-	-	-	2.5

3.- VARIATIONS.
The instruments are not designed for field modification. Each option must therefore be specified in the order. The electrical connection is single phase.

3.2.- VOLTAGE INPUTS.

12, 24, 48 or 125 V DC

3.3.- CURRENT INPUTS.

Direct up to 40 A. Indirect with 60 mV shunt.

3.4.- AUXILIARY VOLTAGE.
Self-powered.

3.5.- SERIAL OUTPUT.

RS485.

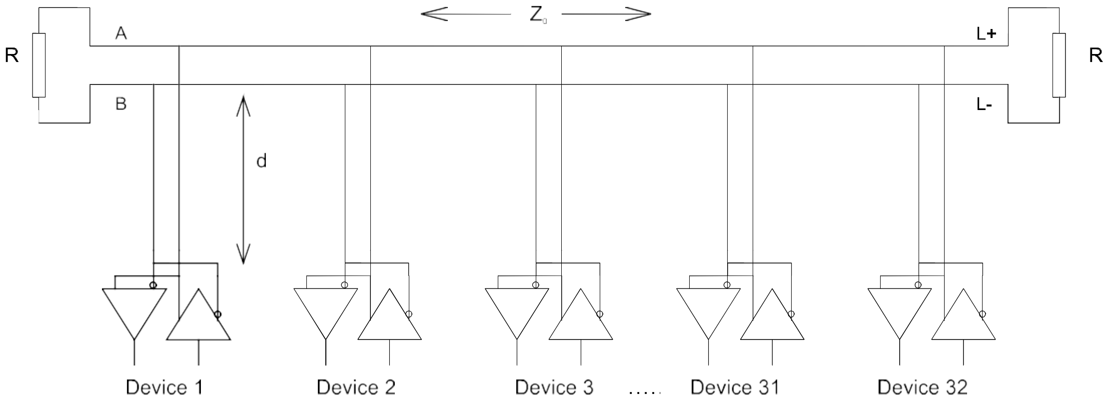
3.6.- DIGITAL OUTPUTS.
Optical coupler:
 Duration 100< T1 <200 ms.
 Time between pulses: T2 >200 ms.

5.- WIRING.

5.1.- ELECTRICAL CONNECTIONS.
The marking of the terminals is the traditional one for electrical lines.

5.2.- SERIAL LINE.
The communication line uses a terminal block mounted on a printed circuit. The connections are as follows:
RS485: L+ (A)
L- (B)
COM

The RS485 signals are called L+ and L-. They are connected in parallel to the mating terminals as specified in the standard, i.e. all terminals marked L+ are connected to the same wire and all terminals marked L- are connected to the other wire. These terminals are marked DATA A or DATA B on some controllers or converters. A wiring diagram is shown below as a guide.



RS485 TWO WIRE CONNECTION

If the transmission line is more than a few hundred metres long, terminating resistors, nominally 120 ohm, should be fitted. It is always better to terminate the line at the resistors than to leave it unterminated.

5.3.- DIGITAL OUTPUTS.
The optical digital output, by means of a coupler, has several operating modes as shown in the table.

MODE	AO0
0	Active Energy Pulses
1	Digital output
2	Alarm

For mode 0, 1 kWh per pulse is used as a reference value
In Mode 1, the output status is controlled by the host computer.
In mode 2 the alarm level, variable and control mode must be set as described above. The alarm level is always positive and the comparison with it is only made in the module. No control is provided at this value and the user must ensure that it is within the required range.

The optical coupler used allows a maximum load of 48 Vdc and 20 mA on the output. No internal protection is provided and must be provided externally by the user.

6.- COMMUNICATION PROTOCOL.

The AR3DC is equipped with a serial communication line that allows all variables to be sent to a central measurement and control unit. There is only one version: RS485. It allows multidrop communication on a single line with a maximum of 32 terminals, as specified in the standard, and up to a maximum distance of 1200 m.

The serial port is isolated by an Analog Devices circuit with isolation technology capable of withstanding 5 kV isolation. This guarantees the protection characteristics of the equipment and prevents the formation of ground loops on the communication line, which is potential-free and can be connected to ground at a single point in the installation.

The standard RTU MODBUS protocol is used. It is a master-slave protocol, where the master is always in control of the communication and spontaneous messages are not allowed. The transmission speed is fixed at 9600 bps, 8 data bits, no parity, 1 stop bit.

Each transaction consists of a request frame generated by the master and a response frame generated by the slave. When the master sends a write command, an acknowledge frame is returned. There is no response if there are errors, either in the frame structure itself or in the transmission.

The accepted codes are:

03H Read Holding Registers (3xxxx).
04H Read Input Registers (4xxxx).
06H Preset Single Register (6xxxx)
10H Preset Multiple Registers

- **DESCRIPTION OF THE FRAMES.**

- READING ORDERS.

Each frame consists of

- Identity: One byte
- Command code: 04H or 03H
- Data address: Two bytes: H, L
- Number of registers to be read: Two bytes: H, L
- CRC: Two bytes: L, H

- WRITE COMMANDS.

Preset Single register.

- Identity: Single Byte
- Command code: 06H
- Data address: Two bytes: H, L
- Variable value: Two bytes
- CRC: Two bytes: L, H

Preset Several registers

- Identity: One byte
- Command code: 10H
- Data address: Two bytes: H, L
- Number of words to write: Two bytes: H, L
- Number of bytes to write: One byte
- Variable value: Four bytes
- Variable value: Four bytes .
- CRC: Two bytes: L, H

- REPLY FRAME.

Each frame consists of

- Identity: One byte
- Command code (same as received): 04H
- Number of bytes sent: One byte
- Variable value: Four bytes
- Variable value: Four bytes
- CRC: Two bytes: L, H

- ACKNOWLEDGE FRAME.

Consists of :

- Identity: One byte
- Command code (same as received): 10H, 6H
- Data address (same as received): Two bytes: H, L
- Number of words written (same as received): Two bytes: H, L
- CRC: Two bytes: L, H

- MEMORY MAP ADDRESS.

The addressing of the memory map is relative to a base register, - BASE_REG -, located at the first absolute position of the map, at address 0000H.

The actual address of each variable is formed by adding the contents of this register, - BASE_ADD-, and the OFFSET value marked in each table. For example, the actual address of the NETWORK_ID variable, -(offset = 205)-, is formed by adding 205 to the contents of BASE_REG. This addition affects not only the address of each variable, but also the BASE_REG register itself, whose absolute address, in addition to 0H, would be its own value, i.e. [BASE_ADD] + 0H.

In this way, the memory map can be moved to any absolute position, avoiding the problems encountered with some PLCs that have a strict addressing system.
There is a small difference between this protocol and the normal MODBUS protocol in the command codes accepted. These devices accept both 03H and 04H for reading and 06H and 10H for writing. The 10H command can be used to write several 16-bit variables (WORD type) and the 06H command can be used to write a single variable.

This addressing system closely follows the MODBUS requirements for register length. MODBUS considers each register as a 16-bit word. The difference between two successive registers is two bytes. If the variable is four bytes, for example in the case of a floating point variable, the difference is four bytes or two digits in the memory location.

The following tables show the different locations for variables.

- CONFIGURATION VARIABLES.

OFFSET (DEC)	VARIABLE (Name)	Type	R/W	US.	Code	BLOCK R/W
0	BASE_ADD	WORD	R/W	SI	NO	NO
1	ESCALAV	IEEE	R/W	SI	NO	NO
3	ESCALAI	IEEE	R/W	SI	NO	NO
7	ESCALAP	IEEE	R	SI	NO	NO
9	VAL_AL0	IEEE	R/W	SI	NO	NO
200	SER_NUM	WORD(5)	R/W	SI	NO	NO
205	ID	WORD(1)	R/W	SI	NO	NO
206	TIPO	WORD(3)	R/W	SI	NO	NO
32	MODE_OUT	WORD	R/W	SI	NO	NO
50	OUTP	WORD	R/W	SI	NO	NO
33	ALARM0	WORD	R/W	SI	NO	NO
600	SW_RESET	WORD	W	SI	NO	NO

These variables allow the device to be configured.
ESCALAV: This is the primary voltage value. If no voltage transformers are used, this value must be the secondary setting value, i.e. the value shown on the rear label.

ESCALAI: This is the value of the primary current.

VAL_ALx : This is the alarm level above which an alarm is considered for a given variable. This value is expressed as a percentage of the associated variable and can take any value between 1 and 120%.

ATTENTION: If applied to cos, the value must be between 1 and 100%.

SERIAL NUMBER is the manufacturing serial number, unchangeable throughout the life of the instrument.

ID is the address of the instrument when connected to a communication bus. It is a byte and can be any binary value from 0 to 255. The values 0, 255 and 199 should not be used. Care must be taken when using this identity when devices are connected on a network, as they will all accept the command issued.

TYPE indicates the SW version of the device.

MODE_OUT indicates the output relay operating mode according to table 5.3.

OUT_P indicates the status of the relays according to table

B7	B6	B5	B4	B3	B2	B1	B0
0	0	0	0	0	0	0	RELAY0

A relay is activated by writing a '1' to the corresponding bit.

In MODBUS mode, the data is sent:

Mantisa M Mantisa L S+EXP Mantisa H

ALARM0. Its contents indicate which variable each alarm applies to.

B15	B14	B13	B12	B11	B10	B9	B8
MAX/ MIN	ESTATE	-				ACTIVE POWER	
B7	B6	B5	B4	B3	B2	B1	B0
				I1			V

To reset a device, write a 0 to SW_RESET. This has the same effect as turning the power off and on again.

6.2.2 -READ VARIABLES.

These variables can be read at any time. Their meaning is self-explanatory. The SEQUENCE variable indicates the correct sequence of the phases in voltage when it is 0. The sequence check is only carried out when the unit is switched on, so if it is changed later, its content will not be affected.

OFFSET (DEC)	VARIABLE (NAME)	TYPE	R/W	US.	CODE	BLOCK R/W
11	VOLTAGE	IEEE	R	SÍ	NO	SI
13	CURRENT	IEEE	R	SI	NO	SI
15	ACTIVE POWER	IEEE	R	SI	NO	SI

6.2.3.- ENERGY METERS

OFFSET (DEC)	VARIABLE (NAME)	TYPE	R/W	US.	CÓD.	BLOCK R/W
24	ACT_POS	LONG	R/W	SI	NO	NO
26	ACT_NEG	LONG	R/W	SI	NO	NO
28	AH_POS	LONG	R/W	SI	NO	NO
30	AH_NEG	LONG	R/W	SI	NO	NO

6.3 COMMAND.

6.3.1. - READ.

A read command consists of:

ID--- Command type-- Address--- Number of words ---CRCL---CRCH

ID is the identity of the device. Accepted command types are 03H or 04H. Address is the sum of BASE_ADD plus the table offset. Number of words is the number of records to be read and is two bytes. If the variable is a single byte, the number of words is also one.

All data can be accessed individually, but also by block read commands as specified in the tables. The following restrictions must be observed:
The values must all be of the same type, e.g. all IEEE or all binary.
The total block length must not exceed 12.
The following examples assume that BASE_ADD is 1000D (3E8H) and the protocol is MODBUS.

6.3.2 - EXAMPLES OF READ COMMANDS.

Read serial number.

P.:	01H	04H	04H	0B0H	00H	05H	30H	0DEH		
		ID	CMD	DIR		Nº. WORDS		CRCL	CRCH	
R.:		01H	04H	0AH		53H	41H	43H	49H	31H	30H
		ID	CMD	NºBYTES		S	A	C	I	1	0
		31H	32H	35H	41H	0BEH	0F7H				
		1	2	5	A	CRCL CRCH					

Rated voltage (ESCALAV)

P.:	01H	04H	03H	0E9H	00H	02H	0A0H	07BH	
	ID	CMD	DIR		Nº.WORDS		CRCL	CRCH	
R.:	01H	04H	04H	0	0	43H	0C8H	0CBH	22H
	ID	CMD	Nº.BYTES		------------- 400 V ------			CRCL	CRCH

6.4 DATA FORMATS.

The data formats used are as follows.

ASCII: characters e.g. serial number. They are sent in the order specified in the tables. BYTE: Eight bits. For status or control. Sent as words.

WORD: Two bytes. Sent MSB-LSB.

LONG: Four bytes. Sent as MSB --- LSB. (See Appendix 3).

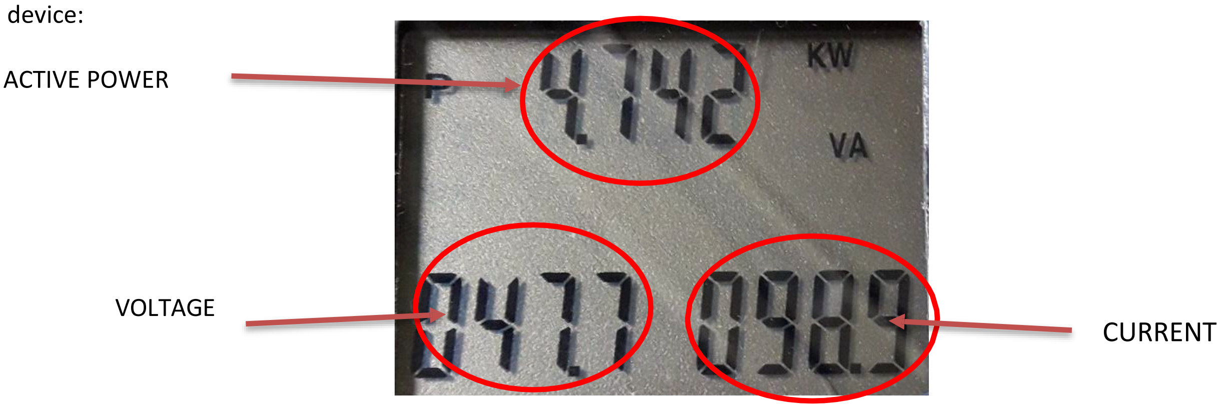
IEEE: Four bytes. S + EXP - Mh - Mm - ML are sent. (See Appendix 3).

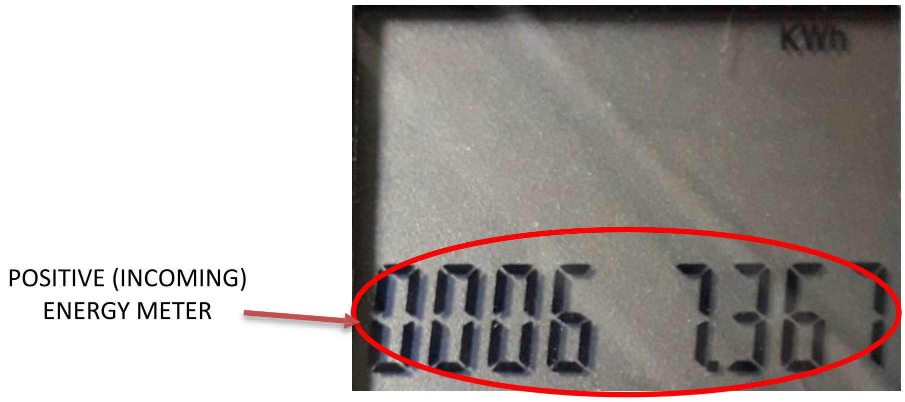
7.- ASSOCIATED SOFTWARE.

An AR3dC V 1.0.1 device management programme is available. It allows to configure and read data from a unit. If there is a network, all units can be accessed by changing the identity, but only one at a time.

Visit the SACI website, www.saci.es, for the latest version of the free application software.

7.1 Display
The different screens that can appear on the unit's display are shown below. They are shown in the order in which they appear on the device:





NEGATIVE ENERGY METER
(OUTGOING)

Ah POSITIVE COUNTER

MODBUS IDENTITY

Ah NEGATIVE COUNTER

8. – SAFETY REQUIREMENTS.

8.1 - Do not connect or disconnect the unit while it is live. As a general rule, do not work on the electrical installation when no other person is present.

8.2 Do not use the unit in an explosive atmosphere or in a damp or condensing environment.

8.3 Do not open the unit or attempt to replace parts inside the unit. For repairs, follow the disassembly instructions and return the unit to the factory.

8.4 Do not operate the unit if the front panel is broken as it may have lost its insulating properties.

8.5 The instruments are not equipped with any type of protection, neither on the voltage circuits nor on the current circuits. The installer must provide a suitable device. It is advisable to install a circuit breaker on the power supply lines to facilitate disconnection of the equipment.

8.6 Units equipped with input transformers can be connected without restriction. However, for basic models equipped with shunts on their current inputs, the installer must take into account that there is a common point between the shunts which also coincides with the neutral of the mains. **As a result, the secondaries of the instrument transformers cannot be connected to earth, which generally reduces the safety conditions and can lead to loops with harmful currents**. The user must take into account that if the neutral is disconnected, _- or does not exist -, a dangerous voltage may appear on the secondary of the instrument transformers if one of the phases is disconnected.

APPENDIX 1. CRC ALGORITHM TYPE 'CRC16'.

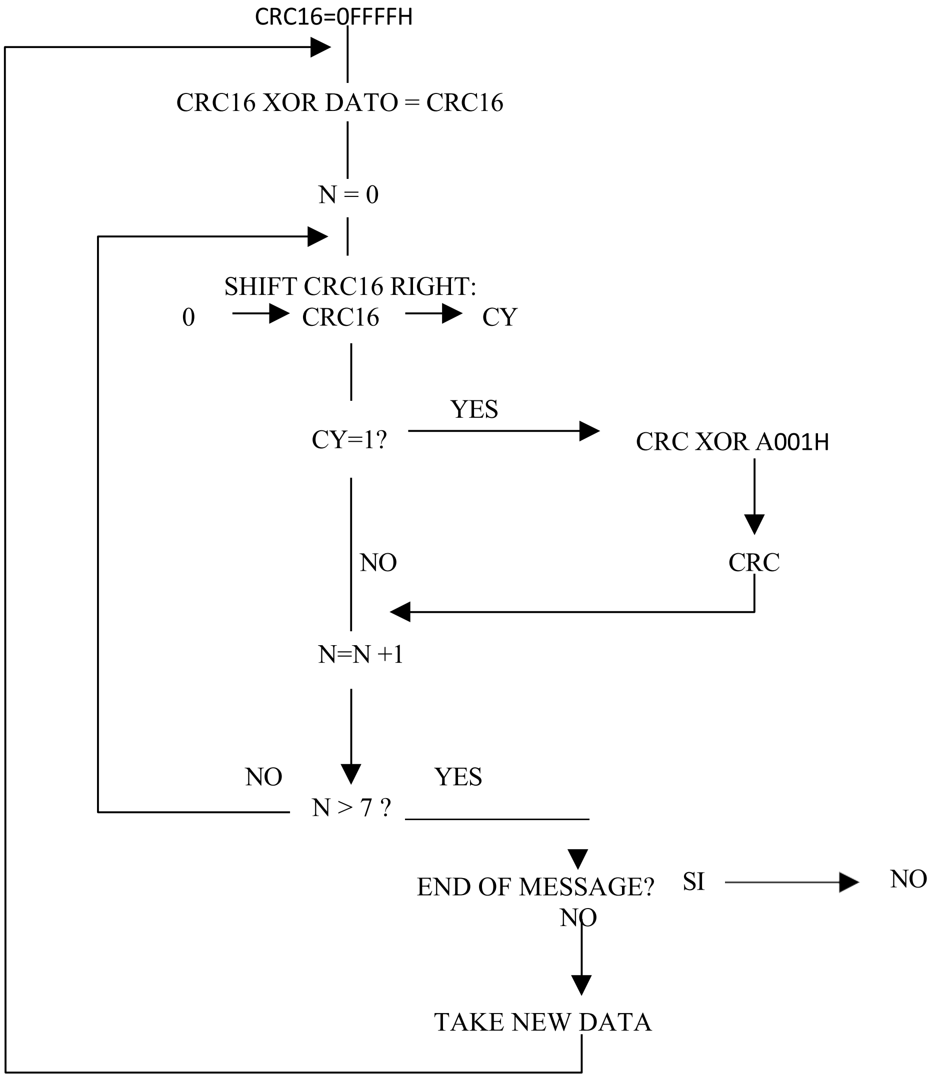
- GENERATOR POLYNOMIAL.

The polynomial used is

$X^{16} + X^{15} + X^{2} + 1 = 18005H$

To calculate the CRC, the polynomial is inverted, leaving out the least significant bit.
CRC16 POLYNOMIAL : 1 1000 0000 0000 0101 = 18005H
WORKING POLYNOMIAL : 1010 0000 0000 0000 0001 = A001H.

- ALGORITHM.



“DATO” is the byte received or to be transmitted.
“CRC16” is a 16-bit word. The result of the operation is also left in CRC16. If the received CRC is included in the algorithm, the final result will be zero.

APPENDIX 2. NOTATION USED (IEEE 754).

IEEE754 notation is used for floating point numbers. Since the accuracy obtained with this type of notation is much higher than the accuracy of the instrument, the byte corresponding to the low mantissa is always zero. In certain cases, this may result in a small discrepancy between the data written by the host computer and the data read. For example, a number such as 220,000 may be read from the instrument as 219,987.

BYTE1	BYTE2	BYTE3	BYTE4
SIGNO+	MANTISA	MANTISA	MANTISA
EXPONENT	HIGH	MEDIUM	LOW

SIGN: sign of the number.
0H means a positive number.
1H means a negative number.

MANTISA: FRACTION 0, XXX XXXX XXXX XXXX XXXX XXXX
M1 M23

EXPONENT: The exponent of the number at offset 127.
0: 127. (7FH)
1: 128. (80H)
-1: 126. (7EH)

To calculate the value:

VALOR: $(-1)^{S} * 2^{EXP-127} * (1+ FRACTION)$

FRACTION: $\sum_{i=1}^{i=23} 2^{-i} * M(i)$

The byte configuration is as follows:

BYTE1:

7	6	5	4	3	2	1	0
SIGN -------		EXPONENT			----------		
E7	E6	E5	E4	E3	E2	E1	

BYTE2:

7	6	5	4	3	2	1	0
EXP ---------	MANTISA HIGH			--------			
E0	M1	M2	M3	M4	M5	M6	M7

BYTE3:

7	6	5	4	3	2	1	0
-------------- MANTISA			MEDIUM-------				
M8	M9	M10	M11	M12	M13	M14	M15

BYTE4: (Siempre nulo).

7	6	5	4	3	2	1	0
-------------- MANTISA LOW --------							
M16	M17	M18	M19	M20	M21	M22	M23

ANNEX 3. DATA TRANSMISSION FORMAT .

Data is sent in IEEE format:

1. BYTE SIGN + EXPONENT
2. HIGH BYTE MANTISSA
3. MIDDLE BYTE MANTISSA
4. LOW BYTE MANTISSA (ALWAYS ZERO)

This mode of transmission is called JBUS MODE.
In some applications the order is reversed:

1. MIDDLE BYTE MANTISSA
2. LOW MANTISSA BYTE (ALWAYS ZERO)
3. BYTE SIGN + EXPONENT
4. HIGH MANTISSA BYTE

This mode of transmission is called MODBUS.
The standard protocol is MODBUS.

This difference also applies to numbers in LONG format:
MSB, msb, LSB, lsb corresponds to the JBUS format.
LSB, lsb, MSB, msb corresponds to the MODBUS format.

ANNEX 4. CALCULATION OF THE CRC.

Example of calculation in QBASIC:

```
function crc16 (txt, lon) AS INTEGER
        DIM flag AS LONG
        DIM crc AS LONG
        DIM car AS INTEGER
        DIM bit AS INTEGER
        CRC= &HFFFF&
        FOR car =1 TO LON
                crc = crc XOR ASC(MID$ ( txt, car, 1))
                FOR bit = 0 TO 7
                        flag = crc AND 1&
                        crc = crc\ 2&
                        IF flag = 1 THEN
                                crc= crc XOR &HA001&
                END IF
        NEXT bit
        NEXT car
        crc16 = INT (crc AND &HFFFF&)
END FUNCTION
```

Example of a calculation in C:

```
        Void Saci_CalculoCRC ( unsigned char *Mensaje, int NumeroDeElementos)
{
        long flag, crcx;
        int car,bit;
        unsigned char v1,v2;
        crcx= 0xffff;
        for (car=0; car < NumeroDeElementos; car++)
        {
                crcx = crcx ^ Mensaje[car];
                for (bit=0; bit <8; bit++)
                {
                        flag= crcx & 1
                        crcx = crcx >>1 ;
                        if ( flag== 1 ) { crcx = crcx ^ 0xa001; }
                }
        }
        crcx= crcx & 0xffff;
        v1 = ( unsigned char) abs (crcx / 256 );
        v2 = ( unsigned char ) crcx – (v1*256);
        Message [NumberOfElements] = v2;
        Message [NumberOfElements +1] = v1;
```

To check the message, the CRC is calculated including the received CRC bytes. If the result is zero, the message is correct.