GUIDELINES ON MODBUS COMMUNICATION WITH CADEL METERING PRODUCTS

1. Scope

CADEL Products that can be integrated into networks include Metering Products and Control Products.

This document is intended to provide information and guidance to customers who desire to use CADEL Metering Products (including those with built-in control outputs) for integration into networks for centralized monitoring and control, and develop their own software for the applications intended.

For integration into a centralized network the CD 7xx series of CADEL products should be selected as these support communication over an RS 485 multi-drop network employing Modbus RTU Protocol.

2. Network Structure

CADEL products are designed to work in the half-duplex mode with the central PC functioning as the Master and the nodes as Slaves.

The network should be built up with shielded cables meeting the Resistance and Capacitance requirements given in Application Note APP 024. Higher values of Resistance or Capacitance can result in excessive attenuation of the signals and errors in data transmission.

The length of cable in each link of the network should not exceed 1000 metres. Each link comprises two signal lines and a common signal return and can have up to 30 CADEL CD 7xx meters on it. It is recommended that the conducting shield of the cable be used as the signal return path.

For detailed guidelines on setting up an RS 485 Multi-drop Cable Network refer to Application Note APP 024.

3. Bus Termination

Each cable link should be terminated at both ends by the characteristic impedance of the cable. For cables conforming to Resistance and Capacitance requirements given in the Application Note APP 024, recommended terminating impedance is 120 ohms.

While connecting an individual Meter to the cable the shortest possible stub should be used. If the stub is not short it will give rise to signal distortion, which may lead to errors in data transmission.

4. Communication Parameters

Cadel Meters can be configured to work at the following baud rates and other options as under

Speed	1200 / 2400 / 4800 / 9600 / 19200 Bauds

Other options that need to be configured are :

	OPTION1	OPTION2	OPTION3
Start bit	1	1	1
Parity	None	EVEN	ODD
Stop bit	2	1	1

All Meters in the Network should be configured for the same Baud Rate and the same Option

5. CRC-16 Cyclic Redundancy Check

CRC-16 Cyclic Redundancy Check is employed in CADEL Meters for ensuring integrity of data. Data collection software should also have an identical check.

The CRC-16 error check sequence is implemented as described in the following paragraphs.

The message, (data bits only, disregarding start/stop and parity bits), is considered as one continuous binary number whose most significant bit, (MSB), is transmitted first. The message is pre-multiplied by X**16, (shifted left 16 bits), then divided by X**16 + X**15 + X**2 + 1 expressed as a binary number (11000000000000101). The integer quotient digits are ignored and the 16-bit remainder (initialized to all ones at the start to avoid the case where all zeroes being an accepted message), is appended to the message, (MSB first), as the two CRC check bytes. The resulting message including the CRC, when divided by the same polynomial (X**16 + X**15 + X**2 + 1), at the receiver will give a zero remainder if no errors have occurred. (The receiving unit recalculates the CRC and compares it to the transmitted CRC). All arithmetic is performed modulo two, (no carries). An example of the CRC-16 error check for message HEX 0207, (address 2, function 7 or a status request to slave number 2) follows:

The device used to serialize the data for transmission will send the conventional LSB or right-most bit of each character first. In generating the CRC, the first bit transmitted is defined as the MSB of the dividend. For convenience then, and since there are no carries used in arithmetic, let's assume while computing the CRC that the MSB is on the right. To be consistent, the bit order of the generating polynomial must be reversed. The MSB of the polynomial is dropped since it affects only the quotient and not the remainder. This yields 1010 0000 0000 0001, (HEX A001). Note that this reversal of the bit order will have no effect whatever on the interpretation or the bit order of characters external to the CRC calculations.

The step by step procedure to form the CRC-16 is as follows:

a. Load a 16-bit register with all 1's.
b. Exclusive OR the first 8-bit byte with the high order byte of the 16-bit register, putting the result in the 16-bit register.
c. Shift the 16-bit register one bit to the right.
d. If the bit shifted out to the right is one, exclusive OR the generating polynomial 1010 0000 0000 0001 with the 16-bit register.
e. If the bit shifted out to the right is zero; return to step c.
f. Repeat steps c and d until 8 shifts have been performed.
g. Exclusive OR the next 8-bit byte with the 16-bit register.
h. Repeat step 3 through 6 until all bytes of the message have been exclusive OR'rd with the 16-bit register and shifted 8 times.

i. The contents of the 16-bit register are the 2 byte CRC error check and is added to the message most significant bits first.

6. Protocol

The meter supports data communications as per Modbus Protocol with RTU data coding. It supports functions for data transfer as given in the following paragraphs.

7. RTU Framing

Frame synchronization can be maintained in RTU transmission mode only by simulating a synchronous message. The receiving device monitors the elapsed time between receipt of characters. If three and one-half character times elapse without a new character or completion of the frame, then the device flushes the frame and assumes that the next byte received will be an address.

T1,T2,T3	ADDRESS	FUNCTION	DATA	CHECK	T1,T2,T3
	8-BITS	8-BITS	N X 8-BITS	16-BITS	

8. Address Field

The address field immediately follows the beginning of frame and consists of 8-bits, (RTU char). These bits indicate the user assigned address of the slave device that is to receive the message sent by the attached master.

Each slave must be assigned a unique address and only the addressed slave will respond to a query that contains its address. When the slave sends a response, the slave address informs the master which slave is communicating. In a broadcast message, an address of 0 is used. All slaves interpret this as an instruction to read and take action on the message, but not to issue a response message.

9. Function Field

The Function Code field tells the addressed slave what function to perform. MODBUS function codes are specifically designed for interacting with a slave on the MODBUS industrial communications system. The high order bit in this field is set by the slave device to indicate an exception condition in the response message. If no exceptions exist, the high-order bit is maintained as zero in the response message.

CODE	MEANING	ACTION
04	READ INPUT REGISTER	Obtains current binary value in one or more input registers.
06	PRESET SINGLE REGISTER	Place a specific binary value into a holding register.
08	DIAGNOSTIC	Echoes back the query for connection checking
17	REPORT SLAVE ID	Identification of the device

10. Data Field

The data field contains information needed by the slave to perform the specific function or it contains data collected by the slave in response to a query. This information may be values, address references, or limits. For example, the function code tells the slave to read a holding register, and the data field is needed to indicate which register to start at and how many to read. The imbedded address and data information varies with the type and capacity of the slave.

11. Error Check Field

This field allows the master and slave devices to check a message for errors in transmission. Sometimes, because of electrical noise or other interference, a message may be changed slightly while its on its way from one device to another. The error checking assures hat the slave or master does not react to messages that have changed during transmission. This increases the safety and the efficiency of the MODBUS system.

The error check field uses a CRC-16 check.

12. Exception Responses

Programming or operation errors are those involving illegal data in a message, or difficulty in communicating with a slave. These errors result in an exception response from either the master computer software or the slave, depending on the type of error. The exception response codes are listed below. When a slave detects one of these errors, it sends a response message to the master consisting of the slave address, function code, error code, and error check fields. To indicate that the response is a notification of an error, the high-order bit of the function code is set to one.

CODE	NAME	MEANING
01	ILLEGAL FUNCTION	The message function received is not an allowable action for the addressed slave.
02	ILLEGAL DATA ADDRESS	The address referenced in the data field is not an allowable address for the addressed slave device.
03	ILLEGAL DATA VALUE	The value referenced in the data field is not allowable in the addressed slave location.
04	FAILURE IN ASSOCIATED DEVICE	The slave's PC has failed to respond to a message or an abortive error occurred.
05	ACKNOWLEDGE	The slave PLC has accepted and is processing the long duration program command.
06	BUSY, REJECTED MESSAGE	The message was received without error, but the PLC is engaged in processing a long duration program command.
07	NAK-NEGATIVE ACKNOWLEDGMENT	The PROGRAM function just requested could not be performed.

13. Read Input Registers (Function Code 04)

Function Code 04 obtains the contents of the controllers input registers. These locations receive their vales from devices connected to the I/O structure and can only be referenced, not altered from within the controller nor via MODBUS.

The example below requests the content of register 30009 in slave number 17.

ADDR	FUNC	DATA START PT HO	DATA START PT LO	DATA # OF REGS HO	DATA # OF REGS LO	ERROR CHECK FIELD
11	04	00	08	00	01	CRC

In the response message, the content of register 30009 is decimal value 0.

ADDR	FUNC	BYTE COUNT	DATA INPUT REG HO 30009	DATA INPUT REG LO 30009	ERROR CHECK FIELD
11	04	02	00	00	CRC

14. Preset Single Register (Function Code 06)

Function 06 allows the user to modify the contents of a holding register. Any holding register that exists within the controller can have its contents changed by this message. The values are provided in binary up to the maximum capacity of the controller. Unused high-order bits must be set to zero. When used with slave address 00, all slave controllers will load the specified register with the contents specified.

ADDR	FUNC	DATA REG HO	DATA REG LO	DATA VALUE HO	DATA VALUE LO	ERROR CHECK FIELD
11	06	00	87	03	9E	CRC

The normal response to a preset single register request is to retransmit the query message after the register has been altered.

ADDR	FUNC	DATA REG HO	DATA REG LO	DATA VALUE HO	DATA VALUE LO	ERROR CHECK FIELD
11	06	00	87	03	9E	CRC

15. Diagnostic Function (Function Code 08)

Function 08 with sub function code 00 00 allows the user to send a query message and receive the same back for testing the communications path.

ADDR	FUNC	DIAG SUB CODE HO	DIAG SUB CODE LO	DATA VALUE HO	DATA VALUE LO	ERROR CHECK FIELD
11	08	00	00	A5	5A	CRC

The slave device will return the same back as a response

16. Report Slave ID (Function Code 17)

Function 11 HEX will return the slave identification information. Broadcast not allowed.

ADDR	FUNC			ERROR CHECK FIELD
11	11			CRC

The slave device will return response as

ADDR	FUNC	BC	DATA……………………………..	ERROR CHECK FIELD	
11	11	0C	DB1HI DB1LO .. DB6HI DB6LO	CRCLO	CRCHI

Where in the data byte will contain meter information as under

CADEL SIGN		MODEL NUMBER				VER NUM	
B1HI	B1LO	B2HI	B2LO	B3HI	B3LO	B4HI	B4LO
C	D	7	5	5	V	7	0

17. Modbus Register Definitions

0XXXX REFERENCE REGISTERS - **DISCRETE INPUTS - READ ONLY**

REGISTER	CONTENTS	R/W	MIN VALUE	MAX VAL
00001-22	RESERVED	R	0	1
00023	RELAY STATUS	R	0	1
00024	SYSTEM PF SIGN	R	0	1
00025	ACTIVE POWER_R SIGN	R	0	1
00026	ACTIVE POWER_Y SIGN	R	0	1
00027	ACTIVE POWER_B SIGN	R	0	1
00028	REACTIVE POWER_R SIGN	R	0	1
00029	REACTIVE POWER_Y SIGN	R	0	1
00030	REACTIVE POWER_B SIGN	R	0	1
00031	LOAD IDLE / NORMAL	R	0	1
00032	INPUT VOLTAGE TYPE	R	0	1

RELAY STATUS		SYSTEM PF SIGN		ACTIVE POWER SIGN		REACTIVE POWER SIGN		LOAD STATUS		INPUT VOLTAGE	
0	NORMAL	0	LEAD	0	REVERSE	0	PF LEAD	0	IDLE	0	HT
1	OPERATED	1	LAG	1	NORMAL	1	PF LAG	1	NORMAL	1	LT

3XXXX REFERENCE REGISTERS - **INPUT REGISTERS - READ ONLY**

REG	CONTENTS	R/W	MIN_VAL	MAX_VAL	UNIT
30001	0XXXX bits 1 to 16	R			
30002	0XXXX bits 17 to 32	R			
30003	CT AMPS		1	9999	AMPS
30004	PT VOLTS HI		110v	999000	VOLTS
30005	PT VOLTS LO				
30006	KWH HI	R	0	999999	KWH
30007	KWH LO				
30008	POWER FACTOR	R	0	1000	0.001 PF
30009	ACTIVE POWER W	R	0	2^16	0.01% FSKVA
30010	APPARENT POWER VA	R	0	2^16	0.01% FSKVA
30011	REACTIVE POWER VAR	R	0	2^16	0.01% FSKVA
30012	CURRENT IR	R	0	2^16	0.01% FSCUR
30013	CURRENT IY	R	0	2^16	0.01% FSCUR
30014	CURRENT IB	R	0	2^16	0.01% FSCUR
30015	VOLTAGE V_RY	R	0	2^16	0.01% FSV
30016	VOLTAGE V_YB	R	0	2^16	0.01% FSV
30017	VOLTAGE V_BR	R	0	2^16	0.01% FSV
30018	KVAH HI	R	0	999999	KVAH
30019	KVAH LO				
30020	FREQUENCY FR	R	0	2^16	0.1 Hz
30021	KVARH+ HI (LGPF)	R	0	999999	KVARH
30022	KVARH+ LO				
30023	KVARH- HI (LDPF)	R	0	999999	KVARH
30024	KVARH- LO				
30025	VOLTAGE VRN	R	0	2^16	0.01% FSV
30026	VOLTAGE VYN	R	0	2^16	0.01% FSV
30027	VOLTAGE VBN	R	0	2^16	0.01% FSV
30028	ACTIVE KW_R	R	0	2^16	0.01% FSKVA
30029	ACTIVE KW_Y	R	0	2^16	0.01% FSKVA
30030	ACTIVE KW_B	R	0	2^16	0.01% FSKVA
30031	APPARENT VA_R	R	0	2^16	0.01% FSKVA
30032	APPARENT VA_Y	R	0	2^16	0.01% FSKVA
30033	APPARENT VA_B	R	0	2^16	0.01% FSKVA
30034	REACTIVE VAR_R	R	0	2^16	0.01% FSKVA
30035	REACTIVE VAR_Y	R	0	2^16	0.01% FSKVA
30036	REACTIVE VAR_B	R	0	2^16	0.01% FSKVA
30037	FUTURE USE				

4XXXX REFERENCE REGISTERS - **HOLDING REGISTERS - READ /WRITE**

REG	CONTENTS	R/W	MIN_VAL	MAX_VAL	UNITS
40001	RELAY CONTROL	W			
40002	RESERVED				
40003	RESERVED				
40004	RESERVED				

RELAY CONTROL	
0XAAAA	NON-OPERATE
0X5555	OPERATE

VALUE VALIDATION NEEDED IN APPLICATION FOR CT / PT

** THE CT PRIMARY MINIMUM CAN BE DECIDED BY THE LAST DIGIT IN MODEL NO ODD - 5 AMPS / EVEN – 1 AMP

* VOLTAGE CIRCUIT TYPE (00032) CAN FIX MIN-MAX FOR THIS FIELD. LT CIRCUIT CAN HAVE MIN/MAX OF 415 VOLTS WHERE AS HT CAN HAVE MIN 110 VOLTS, MAX 999000 VOLTS.

18. Computation of Full Scale – an example

INSTANTANEOUS VALUES

CT and PT Ratios and Communication Parameters can be set or edited only from the front panel of the instrument.

CT and PT values can only be read from input registers. These parameters are stored in 16-bit normalized format. The computation of actual live values can be done as under.

Read CT value from input register 30003

AMPS_FS = REG30003

Read PT value from input registers 30004 and 30005

VOLTS_FS = (REG30004 * 65536) + REG30005

PF = (REG30008 / 1000)

PF_SIGN = REG00024

Now compute Full Scale Power (3 phase) as

POWER_FS = (1.732 * VOLTS_FS * AMPS_FS) watts

Now compute

Voltage
VRY = ((REG30015 * VOLTS_FS) / 10000) volts

Current
IR = ((REG30012 * AMPS_FS) / 10000) amps

Power
KW = (REG30009 * POWER_FS) / 10000 watts

FREQUENCY = (REG30020 / 10) hertz

and so on.

Modify the expression for the desired precision / display format.

CUMULATIVE VALUES

The contents of the energy registers will provide the present accumulated values as

KWH = ((REG30006 * 65536) + REG30007) kWh

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