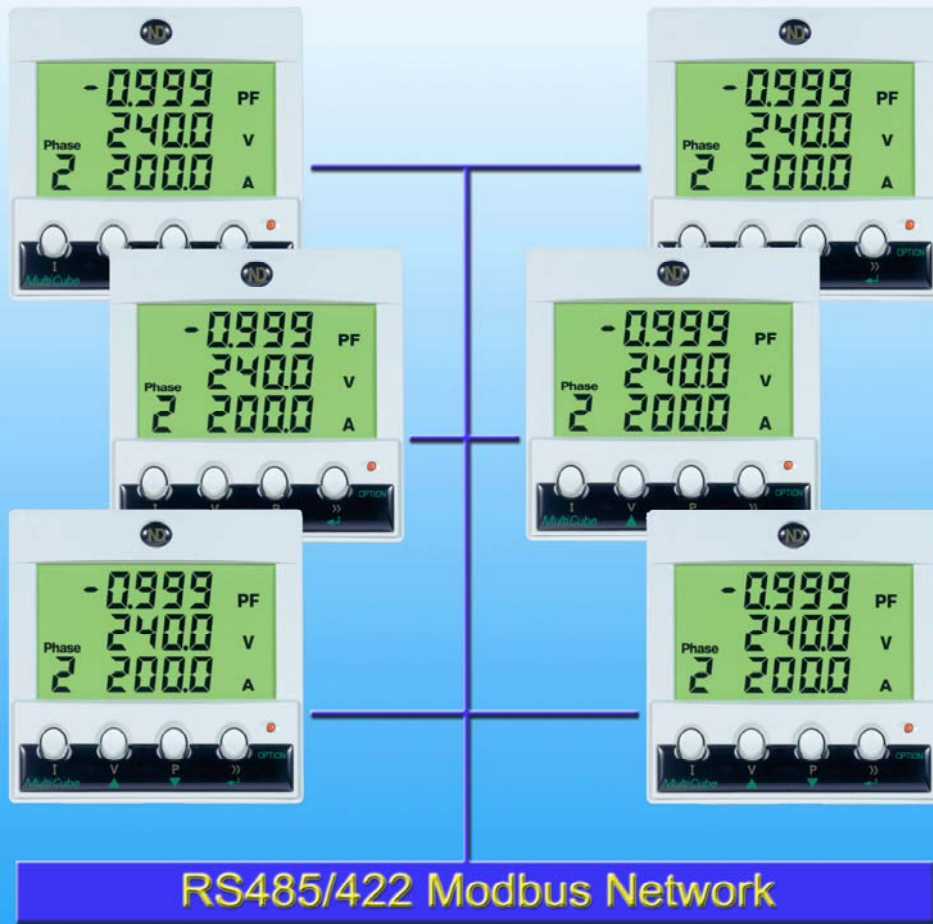


MultiCube

Multi-Function Electricity Meter



Serial Communications Options

PREFACE

| |
|--|
| <p>MultiCube Modbus Serial Communications Installation and Protocol Guide Revision 1.02 February 2003</p> |
|--|

This manual represents the Modbus serial communications firmware as manufactured at the time of publication. It assumes standard software. Special versions of software may be fitted, in which case you will be provided with additional details.

Every effort has been made to ensure that the information in this manual is complete and accurate. We revised this manual but cannot be held responsible for errors or omissions.

The hardware has been designed and tested in accordance with EN 61010-1, 'Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use'. This operating guide contains information and warnings, which must be followed by the user to ensure safe operation and to maintain the apparatus in a safe condition.

We reserve the right to make changes and improvements to the product without obligation to incorporate these changes and improvements into units previously shipped.

General Editor : Ian Sykes BSc (hons).

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Safety

1. Safety

1.1 Warning Symbols

This manual provides details of safe installation and operation of the Modbus serial communications option. Safety may be impaired if the instructions are not followed. Labels on individual devices give details of equipment ratings for safe operation. Take time to examine all labels on the meter and to read this manual before commencing installation.



CAUTION

Refer to User Instructions



DANGER

Risk of Electric Shock

Figure 1-1 Safety Symbols

WARNING

The equipment contains no user serviceable parts. Installation and commissioning should be carried out by qualified personnel

1.2 Maintenance

The equipment should be maintained in good working order. Damage to the product should be repaired by the manufacturer. The options module may be cleaned by wiping lightly with a soft cloth. No solvents or cleaning agents should be used. All inputs and supplies, to the meter and options module must be isolated before cleaning any part of the equipment.

2. Description

The serial communications option uses a high-speed microprocessor to extract information from a MultiCube meter and provides an interface to an industry standard Modbus system.

Use of a dedicated communications processor ensures optimum efficiency, allowing fast access to data on systems with multiple meters. The use of Modbus protocol ensures compatibility with existing systems and/or a number of readily available software packages.

The RS485/RS422 interface communicates over distances up to 1200 metres with data rates of 4800, 9600 or 19200 to suit system requirements.

2.1 Internally Fitted Modbus Option

The MultiCube may be supplied with the Modbus serial communications firmware added within the standard instrument enclosure. This factory fitted option provides a compact, cost effective solution for RS485 communications only. Connection to the Modbus system is made at the rear of the MultiCube (terminals 25-28) as shown below.

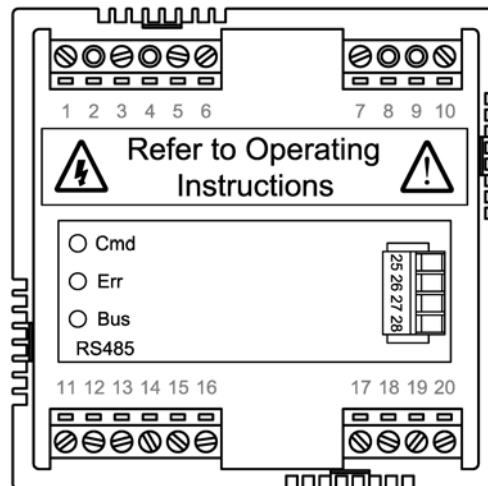


Figure 2-1 Internal Modbus Option

Description

2.2 Retro-Fit Options Module

Modbus serial communications may be retro-fitted to MultiCube meters already installed. The Modbus Options Module, shown below, adds a multi-drop RS485 or RS422 interface to any standard MultiCube meter.

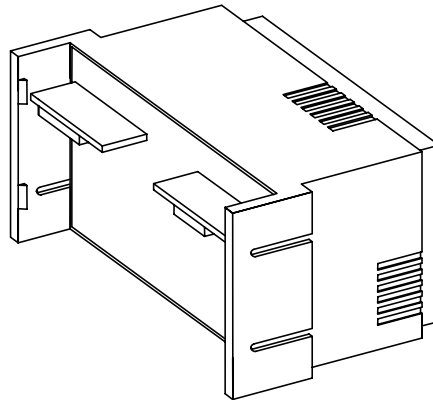


Figure 2-2 Options Module

2.3 Available Parameters

The Modbus Option firmware is available in two forms.

The '**Standard**' form provides access only to those MultiCube parameters, which may be seen on the meters LCD display. The list of parameters available depends on the MultiCube '*Meter Type*'. Parameters not displayed on a particular MultiCube are set to zero in the Modbus tables (refer to section 4.5).

The '**All Value**' form provides access to the complete set of parameters, measured by a Type 4 MultiCube, irrespective of *Meter Type*. Additional parameters measured by Type 6 meters (Tables 17 and 18) are only available from this meter type.

2.4 Attaching The Retro-Fit Options Unit

To retro-fit the Options Module to the MultiCube:

1. Isolate **All** inputs/outputs to the MultiCube.
2. Check the ratings on the options module and meter to ensure compatibility.
3. Use a sharp knife to remove the cutout section from the rear of the MultiCube. Ensure the knife blade does not penetrate > 3mm.
4. Insert the Options Module into the slot on the rear of the meter.
5. Slide the Module fully home until all four mounting lugs 'click' into place as shown below.

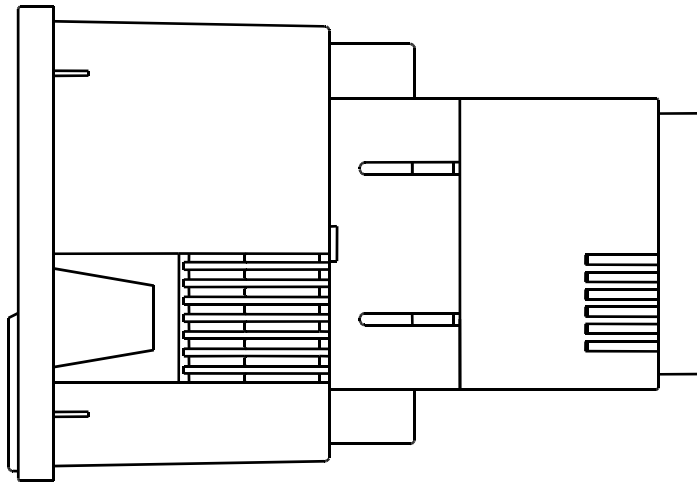


Figure 2-3 Options Module Attached to MultiCube

2.5 Option LED

The MultiCube continually checks for the presence of a healthy Modbus communication option and illuminates the '**Option**' LED on the front panel if validated. If the LED fails to illuminate this may be an indication that no option is fitted or that the retro-fit module is not attached correctly.

Programming

3. Programming

The MultiCube programming menu will automatically expand to include Baud Rate and Address settings when valid Modbus Options hardware is detected.

3.1.1 Setting Baud Rate

Remote serial communications speeds of 4800, 9600 or 19200 may be selected to suit external system requirements. Higher speeds will provide faster data access while a slower speed may be required in electrically noisy environments. Enter programming mode on the MultiCube as described in the Meter Operating Instructions. Scroll through program settings using \downarrow until the meter displays 'Baud Rate'.



Figure 3-1 Setting The Baud Rate

- Press \triangle to select the next highest available baud rate setting.
- Press ∇ to select the next lowest available baud rate setting.
- Press \leftarrow and hold for 2 seconds when done.

3.1.2 Setting Meter Address

Each outstation (Meter) on a multi-drop Modbus system is identified to the master by a unique address. The MultiCube may be addressed anywhere in the full Modbus range of 1-247.

Enter programming mode on the MultiCube as described in the Meter Operating Instructions. Scroll through program settings using \downarrow until the meter displays 'Cube Addr'.



Figure 3-2 Setting The Modbus Address

Press \triangle to increment the Modbus Address.

Press ∇ to decrement the Modbus Address.

Press \leftarrow and hold for 2 seconds when done.

4. Modbus Communication

4.1 Description

The MultiCube Modbus Option provides a serial communications interface to external systems. This allows remote reading and programming of the meter by a host computer (e.g. PC). The communication protocol used is a subset of Modicon's Modbus enabling use of standard off the shelf software packages and connection to standard controllers.

4.1.1 Communication Address

Each meter on a Modbus serial communication network must be assigned a unique address between 1 and 247. This is carried out in programming mode as described in Section 3. If two or more meters, connected in a multi-drop network have the same address, data on the network will be corrupted and communication will fail.

4.1.2 Data Format

The device uses a fixed data format for serial communications:

| | | |
|-------------|-------------|------------|
| 1 Start Bit | 8 Data Bits | 1 Stop Bit |
|-------------|-------------|------------|

The 8 data bits are always transmitted least significant bit first. This data byte is binary coded.

The baud rate is programmable as **4800, 9600, or 19200 baud**. This is carried out in programming mode as described in Section 3.

4.2 RS485

4.2.1 Description

RS485 communication on the MultiCube enables connection of up to 128 meters on a single pair of wires (247 with repeaters). This pair is used for transmission and reception with each meter (and the host) automatically switching data direction. The host should be fitted with an RS485 driver (or converter) capable of operation in two-wire mode (half duplex).

PC operation in RS485 two-wire mode usually requires software control of the data direction. This controls the line drivers connected to the bus at the host serial port. This direction control requires high-speed operation and may be problematic under certain multi-tasking operating systems such as Windows. It is advisable to check with the software vendor before selecting software direction control as the mode of operation. If software data direction control is not suitable, RS232-RS485 converters are available for standard PCs, which carry out automatic hardware direction control. For more information on these contact your distributor.

Each Modbus serial transaction is preceded by a device address allowing the host to temporarily communicate with a specific meter on the bus. Certain commands allow the host to communicate with all meters simultaneously. These commands are known as **broadcasts** and use address 0.

Modbus Communication

4.2.2 Cable Selection

A dedicated, screened twisted pair cable is required to provide a basic RS485 connection. A second twisted pair may be used for 0V connection if required. The cable should be chosen to suit the data rate and maximum length to be installed. The EIA RS-422/485-A standard provides curves that relate cable length to data rate for 24 AWG screened, twisted pair, telephone cable with a shunt capacitance of 50pf/m. For baud rates up to 19,200 the standard suggests a maximum length of 1200m for this type of cable. If other types of cable are to be used it is recommended that the cable supplier is consulted as to the suitability for use with RS485 to 19,200 baud.

4.2.3 Signal 0V and Cable Shield

A signal 0V termination is provided on each meter. Although RS485 does not strictly require a signal 0V, it is recommended this be connected as shown in the diagram below. This creates a known reference for the isolated RS485 system thereby reducing potential common-mode errors in the meter's driver circuit. A cable shield is used to attenuate noise picked up from external sources. This should be continuous, and cover as much of the signal pairs as possible. It is recommended that the shield should be connected to ground at the host only.

4.2.4 Terminating Resistors

In order to minimise signal errors due to noise over long cable lengths, terminating resistors may be fitted. These match the RS485 device impedance to that of the cable. Two 120-ohm resistors, one at the host port terminals and the other at the most remote meter terminals are recommended for this purpose.

4.2.5 Connection To Meters

The bus should be taken to meters at each location for termination, using the meter terminals as a loop in-out connection. The use of spurs should be avoided wherever possible.

4.2.5.1 Internal Modbus Option (RS485)

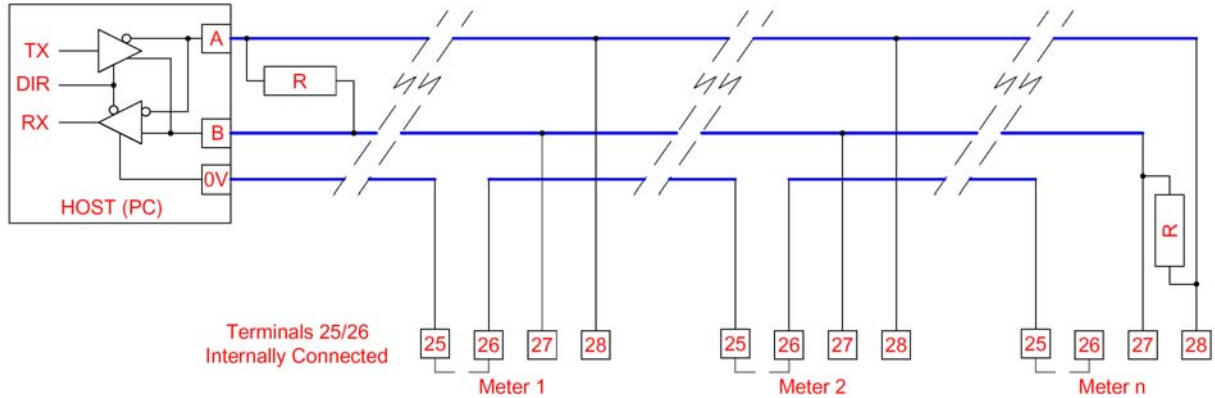


Figure 4-1 Basic RS485 To Internal Modbus Option

4.2.5.2 Retro-Fit Option Module (RS485)

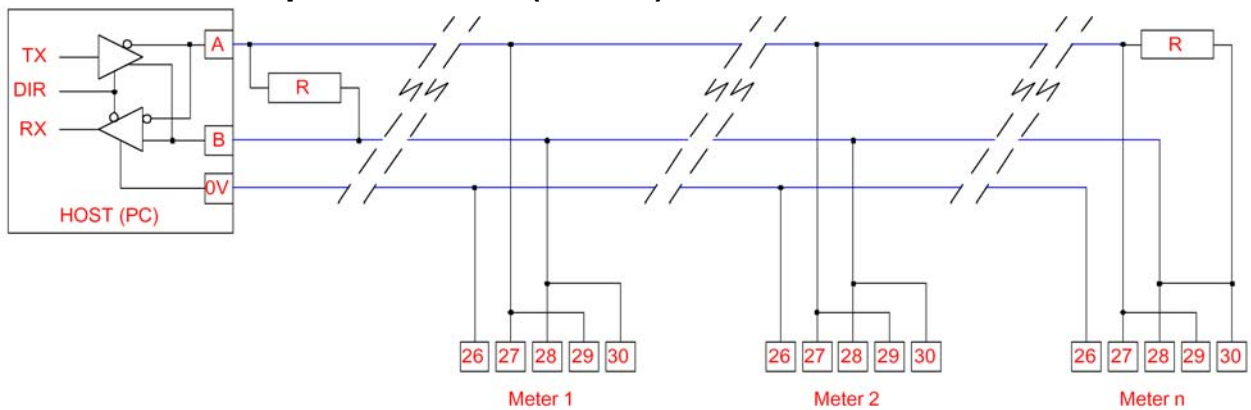


Figure 4-2 Basic RS485 To Retro-Fit Option Module

Modbus Communication

4.2.5.3 Biasing the RS485 System

When an RS485 system is not communicating, all outstations are in high impedance listen mode. In this state no active drivers are present and the bus floats to an unknown state. The logic levels at the output stage of each meter's RS485 circuit will remain at the level of the last bit received. Recommended practice for RS485 networks suggests biasing of the two wires to ensure a known idle state for the networks receivers. Although biasing is not essential it can often provide a solution to a problematic system.

Biasing normally consists of a pull up (usually to an isolated 5V dc supply) and a pull down resistor. The MultiCube has no internal biasing and so connections should be made externally at a single convenient point in the network. A 5V dc external supply with two 470Ω resistors is adequate.

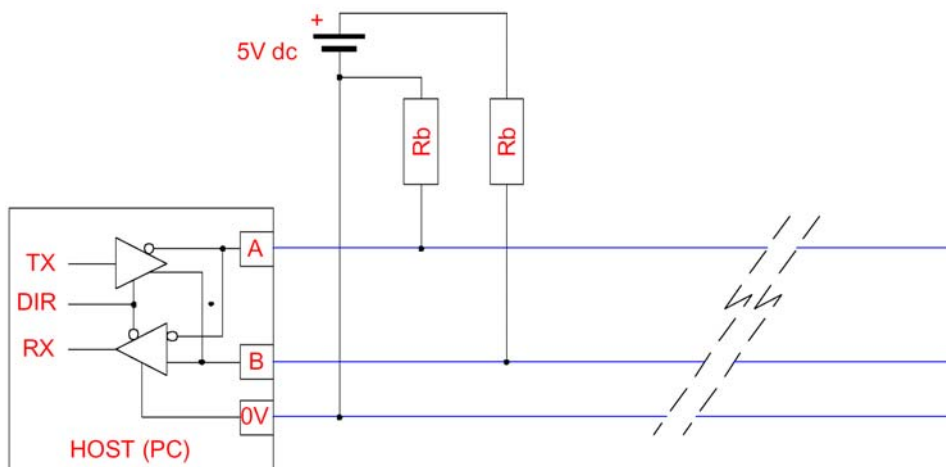


Figure 4-3 RS485 Biasing

4.3 RS422

4.3.1 Description

Note: RS422 is only available on the Retro-Fit MultiCube options module.

The RS422 communication option enables connection of up to 128 meters (247 with repeaters) on two pairs of wires (4-wire bus). One pair is used for transmission and the other for reception.

This connection is more commonly used in full duplex communications systems where host and slave can simultaneously transmit/receive data. In this instance however, the Modbus protocol itself ensures half duplex operation by default.

RS422 may be used in systems where the host computer is not capable of operation in RS485 mode with data direction control. The RS422 standard enables reliable communication over a maximum distance of 1200 metres. Standard line repeaters may be installed to increase the maximum distance of an RS422 network and/or the number of devices, which may be connected.

4.3.2 Cable Selection

Two dedicated, screened twisted pairs are required (one for reception and one for transmission) to provide basic RS422 connection. A third twisted pair may be used for 0V connection if required.

The cable should be chosen to suit the data rate and maximum length to be installed. The EIA RS-422/485-A standard provides curves that relate cable length to data rate for 24 AWG screened, twisted pair, telephone cable with a shunt capacitance of 50pf/m. For baud rates up to 19,200 the standard suggests a maximum length of 1200m for this type of cable. If other types of cable are to be used it is recommended that the cable supplier is consulted as to the suitability for use with RS422 to 19,200 baud.

4.3.3 Signal 0V and Cable Shield

A signal 0V termination is provided on each meter. Although RS422 does not strictly require a signal 0V, it is recommended this be connected as shown in the

Modbus Communication

diagram below. This creates a known reference for the isolated RS422 system thereby reducing potential common-mode errors in the meter's driver circuit. A cable shield is used to attenuate noise picked up from external sources. This should be continuous, and cover as much of the signal pairs as possible. It is recommended that the shield should be connected to ground at the host only.

4.3.4 Terminating Resistors

In order to minimise signal errors due to noise over long cable lengths, terminating resistors may be fitted. These match the RS422 device impedance to that of the cable. Two 120-ohm resistors, one at the host port receive terminals and the other at the most remote meters receive terminals are recommended for this purpose.

4.3.5 Biasing RS422

In certain problematic RS422 networks it may be advantageous to bias each transmission and reception pair. Each twisted pair should be biased separately as shown for the RS485 pair above.

4.3.6 Connection To Meters

The bus should be taken to meters at each location for termination, using the meter terminals as a loop in-out connection. The use of spurs should be avoided wherever possible.

4.3.6.1 Retro-Fit Option Module (RS422)

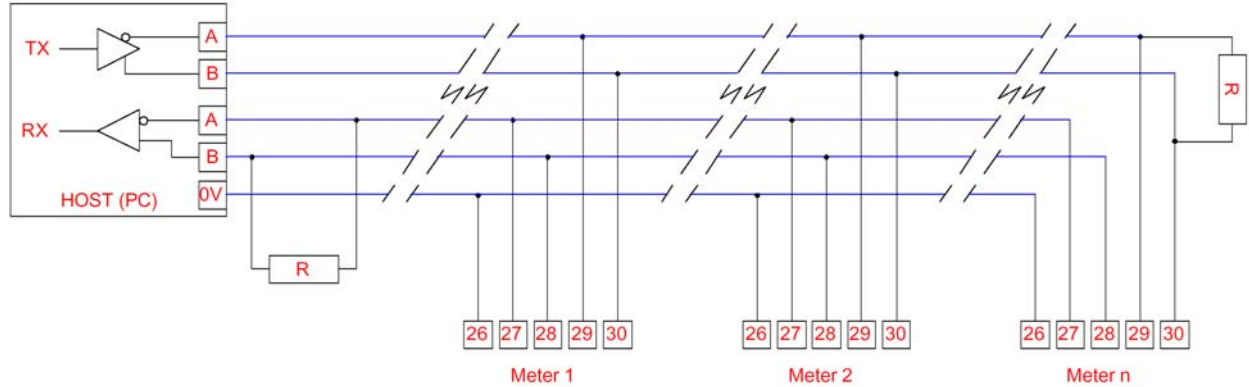


Figure 4-4 Basic RS422 To Retro-Fit Option Module

Modbus Communication

4.4 Modbus Protocol

4.4.1 An Introduction To Modbus

A communication protocol defines a set of commands and data formats which will be recognised by all compatible equipment connected on a system. The protocol effectively forms a communication language.

The MultiCube Options Units utilise a subset of Modicon's 'Modbus' standard protocol. This protocol was originally developed for use by programmable logic controllers (PLCs). It defines a set of commands for reading and/or writing data to devices connected on the bus.

Modbus is a master-slave protocol with all transactions initiated by a single host (e.g. a PC). A single transaction commences with the host transmission of a command packet followed by a slave (Options Unit) reply after a short delay for processing the command.

Command packets consist of an address, a command identifier, data and a checksum for error detection. Each slave device continually monitors the bus looking for activity. Command packets are detected by all slaves but may be acted upon only by the device whose address matches that transmitted.

The host may transmit a **broadcast command**, which uses address 0 to contact all devices on the network. In this instance all slaves act on the command but none of them may reply. This type of command may be useful, for example, in synchronising energy register reset on all meters.

The full Modbus protocol consists of many commands and modes of operation to suit a variety of controllers and applications. The MultiCube Options unit utilises only a few commands and a single transmission mode to perform many functions relevant to metering.

4.4.2 RTU. Transmission Mode

The RTU (Remote Terminal Unit) mode is utilised by the MultiCube Options Unit because it provides the most efficient throughput of data at any particular baud rate.

In RTU mode, the start and end of each message is marked by a silent period of at least 3.5 character periods (Approx. 3.5ms @ 9600 baud). This is shown in the RTU message frame in Figure 4-5 below.

| START | ADDRESS | FUNCTION | DATA | CRC | END |
|---------------|---------|----------|------------|---------|---------------|
| SILENT PERIOD | 8 BITS | 8 BITS | n x 8 BITS | 16 BITS | SILENT PERIOD |

Figure 4-5 RTU Framing

The host (PC) initiates all transactions. Slave devices continuously monitor the network, looking for messages framed by silent periods. The first character detected, after a silent period, is assumed to be an address byte and is compared to the meters internal address (zero for broadcasts). An addressed slave reads the remainder of the message and acts upon it as required.

A slave tests the message to determine it's validity and uses the transmitted checksum (CRC) to detect communication errors. A slave will only act on valid messages, received without error, specifically addressed to it.

ADDRESS

Valid Modbus addresses are in the range 0-247. Individual devices may be assigned addresses in the range 1-247. Address 0 is retained for broadcast commands which are handled by all slaves. When a slave responds to a command it places its own address in the reply message.

Modbus Communication

FUNCTION

The function code is a single byte telling the device what type of operation to perform. Valid Modbus codes are in the range 1-255 decimal but the MultiCube Options Unit handles only a small subset of these as summarised below.

| Function code | Operation | Broadcast |
|---------------|---------------------------|-----------|
| 03 | Read Multiple Registers | No |
| 04 | Read Multiple Registers | No |
| 06 | Preset A Single Register | Yes |
| 08 | Loop Back Diagnostic | No |
| 16 | Preset Multiple Registers | Yes |

Figure 4-6 Function Code Summary

DATA FIELD

Data from the host contains additional information for the remote device specific to the command. For example the data field may specify which meter readings are required or new values for energy registers.

Data from a slave may contain meter readings or other information requested by the host.

The size of the data field varies depending on command type and usage. The data format may also vary from one command to another to suit the application. Instantaneous readings for example are transmitted as 2-byte Integers, whereas energy readings are formatted as 4-byte Long Integers. Data is always transmitted with the most significant byte first. Data formatting is described in more detail in the following sections.

4.4.3 CRC ERROR CHECKING

A 16 bit CRC (*Cyclic Redundancy Check*) field is tagged on to the end of all messages. This field is the result of a CRC calculation performed on the message contents. The CRC field is used by the host and receiving devices alike to determine the validity of the entire message string. A receiving device recalculates the CRC and compares it to the value contained in the message. A slave device ignores a message if the two values do not match.

Note

Use of the CRC is essential when communicating in noisy environments to reduce the effects of erroneous bit errors. The meter will not reply to commands with a CRC in error and the host should re-transmit the command after a pre-determined time-out period. If the host receives a string with a CRC in error the transaction should be re-initiated.

The CRC is calculated on all bytes of a message from the address to the last data byte inclusively. Each bit of the message is processed through the CRC calculation starting with the first bit of the address. The Modbus standard method of CRC calculation requires reversal of the data bytes as they are fed serially through the bit processing routines. A simpler method involves swapping the low and high order bytes of the CRC integer at the end of the calculation. This is shown in the following routine.

Modbus Communication

The calculation is performed as follows:

1. Load a 16 Bit register (“CRC Register”) with FFFF Hex. (All 1’s).
2. Exclusive-OR the first 8 Bits of the message with the low-order byte of the CRC register. Put the result in the CRC register.
3. Shift the CRC register one bit to the right (divide by 2), filling the MSB with a zero.
4. If the bit shifted out in 3 is a 1, Exclusive-OR the CRC register with the value A001 Hex.
5. Repeat steps 3 and 4 until 8 shifts have been performed and the bits tested. A single byte has thus been processed.
6. Repeat steps 2 to 5 using the next 8 bit byte of the message until all bytes have been processed.
7. The final contents of the CRC register is tagged on to the end of the message with the most significant byte first.
8. Swap the low and high order bytes of the integer result

An implementation of the CRC calculation in C code is shown below :


```
unsigned int check_sum(unsigned char *buff, char start, char bytes)
{
    char byte_cnt, bit_cnt;          /* loop counters */
    unsigned int crc_reg;           /* Result register */
    unsigned int CRCHi, CRCLO; /*Low and high order bytes of the crc*/

    crc_reg = 0xFFFF;              /* Set the CRC register to all 1's */

    /* Repeat for each byte of sub string */
    for(byte_cnt=start; byte_cnt<(bytes+start); byte_cnt++)
    {
        crc_reg = crc_reg ^ (unsigned int)buff[byte_cnt]; /*EXOR CRC & Next Byte*/

        /* Test each bit of the CRC */
        for(bit_cnt=0; bit_cnt<8; bit_cnt++)
        {
            if(crc_reg & 0x0001)
            {
                crc_reg = crc_reg >> 1; /* IF LSB=1 EXOR CRC with A001H */
                crc_reg = crc_reg ^ 0xA001; /* Then shift CRC toward LSB */
            }
            else crc_reg = crc_reg >> 1; /* ELSE Shift CRC towards LSB */
        }
    }
    CRCLO=crc_reg>>8; /*Swap the low and high order bytes of the crc result*/
    CRCHi=crc_reg<<8;
    crc_reg = CRCLO+CRCHi;
    return crc_reg;                /* Final CRC register Result */
}
```

Modbus Communication

4.5 Options Unit Data Tables

Data in the MultiCube Options Unit is arranged in several tables for convenience. Individual tables contain like information. Table data may be read only (e.g. instantaneous readings) or read/write access (e.g. CT primary).

Data in each table is pointed to in a Modbus command by two consecutive data address bytes. The first byte defines the table number and the second byte the offset of the data in the table. For example, 'address 2 , 1' would access Table 2, Entry 1 (3-Phase kWh). The Modbus standard defines data addresses using a 16-bit integer. In the case of the MultiCube Options Unit the high byte of this integer represents the table number and the low byte the offset. A Modbus integer address may be calculated as:

$$\text{Modbus Data Address} = (256 \times \text{Table No}) + \text{Table Offset}$$

SIGNED INTEGER

Signed Integers are 16 bit values transmitted as two 8 bit bytes. The most significant byte is always transmitted first. These values vary in the range -32767 to +32767 although some registers have a limited range of acceptable values. The most significant bit defines the sign, zero indicating positives.

UNSIGNED INTEGER

Unsigned Integers are 16 bit values transmitted as two 8 bit bytes. The most significant byte is always transmitted first. These values vary in the range 0 to 65535 although some registers have a limited range of acceptable values.

UNSIGNED LONG INTEGERS (Unsigned Long)

Unsigned long integers are 32 bit values transmitted as four 8-bit bytes. The most significant byte is always transmitted first. These values vary in the range 0 to 4294967295 although energy registers in the MultiCube have a limited range, 0-99999999.

4.5.1 Table 2 Accumulated Energy Readings

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|-----------------|---------------|-------|-------|------------|
| 0 | 512 | Energy Scale Hi | Unsigned Long | 4 | 2 | Read Only |
| 1 | 513 | Energy Scale Lo | | | | |
| 2 | 514 | kWh Hi | Unsigned Long | 4 | 2 | Read/Write |
| 3 | 515 | kWh Lo | | | | |
| 4 | 516 | kVAh Hi | Unsigned Long | 4 | 2 | Read/Write |
| 5 | 517 | kVAh Lo | | | | |
| 6 | 518 | kvarh (Ind) Hi | Unsigned Long | 4 | 2 | Read/Write |
| 7 | 519 | kvarh (Ind) Lo | | | | |
| 8 | 520 | kvarh (Cap) Hi | Unsigned Long | 4 | 2 | Read/Write |
| 9 | 521 | kvarh (Cap) Lo | | | | |

4.5.1.1 Energy Registers

Energy registers available for display on a MultiCube are stored in Modbus Table 2 as unsigned long integers. Registers not available on an individual meter are returned as zero.

4.5.1.2 Writing to Energy Registers

Function 6 or 16 may be used to write to the energy registers in Table 2.

Function 6 allows access to the upper and lower integers of the 4-byte long individually. Upper integers have a maximum write value of 0x0F preventing out of range data being sent to the MultiCube.

Function 16 may be used to access a number of long integers using a single command. This is most useful for setting all registers to 0 simultaneously. Valid commands must send an even number of integers (2 integers per long) starting at an even address in Table 2 (Start of a register). Failure to follow these basic rules will result in an exception response (ref. Section 4.5.15).

Modbus Communication

4.5.1.3 Energy Scaling

Energy readings from the MultiCube are stored as unsigned long integer values with no decimal point or legend (e.g. kWh or MWh). A single scaling factor is provided to enable conversion of the raw data to real numbers in basic unit form (Wh, VAh or varh). The scaling factor is a constant value calculated in the MultiCube as a function of CT and PT Primary programming. To convert raw data to real numbers:

$$E = L \times 10^{(K-3)}$$

Where:

- L** = Long Integer number
- K** = Energy Scaling Factor
- E** = Scaled Energy Result

Example:

If the meter is programmed with CT Primary=50Amps and PT Primary=415V:
The meter displays would be 999999.9 kWh, 999999.9 kVAh and
999999.9 kvarh

The Energy Scaling Factor would be transmitted as: K=5

Energy Registers would be transmitted as: 9999999

Wh would be calculated $9999999 \times 10^{(5-3)} = 9999999 \times 100 = 999999900\text{Wh}$

VAh would be calculated $9999999 \times 10^{(5-3)} = 9999999 \times 100 = 999999900\text{VAh}$

varh would be calculated $9999999 \times 10^{(5-3)} = 9999999 \times 100 = 999999900\text{varh}$

4.5.2 Table 11 Instantaneous Meter Values

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|-----------------|----------------|-------|-------|------------------------|
| 0 | 2816 | kW 3-Ph | Signed Integer | 2 | 1 | Read Only ⁴ |
| 1 | 2817 | kVA 3-Ph | Signed Integer | 2 | 1 | Read Only ⁴ |
| 2 | 2818 | kvar 3-Ph | Signed Integer | 2 | 1 | Read Only ⁴ |
| 3 | 2819 | PF 3-Ph | Signed Integer | 2 | 1 | Read Only |
| 4 | 2820 | Frequency | Signed Integer | 2 | 1 | Read Only |
| 5 | 2821 | Phase 1 Volts | Signed Integer | 2 | 1 | Read Only ² |
| 6 | 2822 | Phase 1 Amps | Signed Integer | 2 | 1 | Read Only ¹ |
| 7 | 2823 | Phase 1 kW | Signed Integer | 2 | 1 | Read Only ⁴ |
| 8 | 2824 | Phase 2 Volts | Signed Integer | 2 | 1 | Read Only ² |
| 9 | 2825 | Phase 2 Amps | Signed Integer | 2 | 1 | Read Only ¹ |
| 10 | 2826 | Phase 2 kW | Signed Integer | 2 | 1 | Read Only ⁴ |
| 11 | 2827 | Phase 3 Volts | Signed Integer | 2 | 1 | Read Only ² |
| 12 | 2828 | Phase 3 Amps | Signed Integer | 2 | 1 | Read Only ¹ |
| 13 | 2829 | Phase 3 kW | Signed Integer | 2 | 1 | Read Only ⁴ |
| 14 | 2830 | Phase 1 PF | Signed Integer | 2 | 1 | Read Only |
| 15 | 2831 | Phase 2 PF | Signed Integer | 2 | 1 | Read Only |
| 16 | 2832 | Phase 3 PF | Signed Integer | 2 | 1 | Read Only |
| 17 | 2833 | Ph1-Ph2 Volts | Signed Integer | 2 | 1 | Read Only ³ |
| 18 | 2834 | Ph2-Ph3 Volts | Signed Integer | 2 | 1 | Read Only ³ |
| 19 | 2835 | Ph3-Ph1 Volts | Signed Integer | 2 | 1 | Read Only ³ |
| 20 | 2836 | Neutral Current | Signed Integer | 2 | 1 | Read Only ¹ |
| 21 | 2837 | Amps Scale | Signed Integer | 2 | 1 | Read Only |
| 22 | 2838 | Ph Volts Scale | Signed Integer | 2 | 1 | Read Only |
| 23 | 2839 | Ln Volts Scale | Signed Integer | 2 | 1 | Read Only |
| 24 | 2840 | Power Scale | Signed Integer | 2 | 1 | Read Only |

- Notes:**
1. Use 'Amps Scale' at Address 2837 to convert to real Amps.
 2. Use 'Ph Volts Scale' at Address 2838 to convert to real Volts.
 3. Use 'Ln Volts Scale' at Address 2839 to convert to real Volts.
 4. Use 'Power Scale' at Address 2840 to convert to real W, VA or var.

Modbus Communication

4.5.3 Table 12 Additional Instantaneous Values

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|--------------|------------|-------|-------|------------------------|
| 0 | 3072 | Phase 1 kVA | Signed Int | 2 | 1 | Read Only ⁴ |
| 1 | 3073 | Phase 2 kVA | Signed Int | 2 | 1 | Read Only ⁴ |
| 2 | 3074 | Phase 3 kVA | Signed Int | 2 | 1 | Read Only ⁴ |
| 3 | 3075 | Phase 1 kvar | Signed Int | 2 | 1 | Read Only ⁴ |
| 4 | 3076 | Phase 2 kvar | Signed Int | 2 | 1 | Read Only ⁴ |
| 5 | 3077 | Phase 3 kvar | Signed Int | 2 | 1 | Read Only ⁴ |

Notes: 4. Use 'Power Scale' at Address 2840 to convert to real W, VA or var.

4.5.4 Table 13 Peak Values

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|------------|------------|-------|-------|---------------------------|
| 0 | 3328 | PK Hold I1 | Signed Int | 2 | 1 | Read/Write ⁵ |
| 1 | 3329 | PK Hold I2 | Signed Int | 2 | 1 | Read/Write ⁵ |
| 2 | 3330 | PK Hold I3 | Signed Int | 2 | 1 | Read/Write ⁵ |
| 3 | 3331 | PK Hold V1 | Signed Int | 2 | 1 | Read/Write ⁶ |
| 4 | 3332 | PK Hold V2 | Signed Int | 2 | 1 | Read/Write ⁶ |
| 5 | 3333 | PK Hold V3 | Signed Int | 2 | 1 | Read/Write ⁶ |
| 6 | 3334 | Peak kW MD | Signed Int | 2 | 1 | Read/Write ^{8,9} |
| 7 | 3335 | MD Period | Signed Int | 2 | 1 | Read/Write ⁸ |
| 8 | 3336 | kW MD | Signed Int | 2 | 1 | Read Only ⁹ |

Notes: 5. Use 'Amps Scale' at Addr 2837 to convert to real peak hold Amps.

6. Use 'Ph Volts Scale' at Addr 2838 to convert to real peak hold V.

8. Peak kW MD & MD Period may **NOT** be written using Command 16.

9. Peak kW MD & MD are scaled as 3-Phase kW/10

4.5.5 Instantaneous/Peak Values

Instantaneous and peak measurements available for display on a MultiCube are stored in Modbus Tables 11-13 as Signed integers. Parameters not available on an individual meter are returned as zero. Negative values are used for per phase/system kvar and PF readings to represent capacitive loads. All other values will be returned as positive integers.

4.5.5.1 Scaling Instantaneous/Peak Values

Instantaneous readings from the MultiCube are provided as signed integer values with no decimal point or legend (e.g. kW or MW). Scaling factors are provided to enable conversion of the raw data to real numbers in basic unit form (amps, volts, watts, VA, or var). These scaling factors are constant values calculated in the MultiCube as a function of CT and PT Primary programming. To convert raw data to real numbers:

$$R = I \times 10^{(K-3)}$$

Where:

- I** = Integer number
- K** = Relevant Scaling Factor
- R** = Real number result

Example:

If the meter is programmed with CT Primary=50Amps and PT Primary=415V:
The meter displays would be scaled as: 50.00A, 240.0V, 415.7V_{LL}, 36.00kW
Scaling factors would be as: I Scale=1, V_{ph} Scale=2, V_{LL} Scale=2, P Scale=4
Integer Values would be transmitted as: 5000, 2400, 4157 and 3600
Amps would be calculated as $5000 \times 10^{(1-3)} = 5000/100 = 50.00A$
Phase Volts would be calculated as $2400 \times 10^{(2-3)} = 2400/10 = 240.0V$
Line Volts would be calculated as $4157 \times 10^{(2-3)} = 4157/10 = 415.7V$
3-Ph Power would be calculated as $3600 \times 10^{(4-3)} = 3600 \times 10 = 36000W$

Power factors are transmitted from the meter in the range -999 to 1000 representing measured values of 0.0 to 1.000. A negative value indicates a capacitive load.

Frequency is transmitted from the meter scaled by a factor of 10. For example a measured frequency of 50.0 would be transmitted as 500.

Modbus Communication

4.5.6 Table 14 Meter Set-up

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|----------------|--------------|-------|-------|--------------------------|
| 0 | 3584 | CT Primary | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 1 | 3585 | PT Primary | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 2 | 3586 | Pulse 1 Rate | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 3 | 3587 | Pulse 2 Rate | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 4 | 3588 | Baud Rate | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 5 | 3589 | Modbus ID | unsigned Int | 2 | 1 | Read/Write ¹⁰ |
| 6 | 3590 | Meter Model | unsigned Int | 2 | 1 | Read Only |
| 7 | 3591 | Meter Type | unsigned Int | 2 | 1 | Read Only |
| 8 | 3592 | Meter Software | unsigned Int | 2 | 1 | Read Only |
| 9 | 3593 | V/I MD Period | unsigned Int | 2 | 1 | Read/Write ¹⁰ |

Notes: 10. Values in Table 14 may not be written using Command 16

4.5.6.1 Meter Set-up Values

Information about the MultiCube's configuration is available in Table 14 as unsigned integers.

- **CT Primary.** (5A - 20000A) CT Primary as displayed during meter set-up.
- **PT Primary.** (60V - 50000V) PT Primary as displayed during meter set-up.
- **Pulse 1 Rate.** (1 - 255) No. of counts of kWh register per pulse (if fitted).
- **Pulse 2 Rate.** (1 - 255) No. of counts of kvarh* register per pulse (if fitted).
- **Baud Rate.** (48, 96 or 192) RS485/422 baud rates of 4800, 9600 or 19200.
- **Modbus ID** (1 – 247). Modbus Meter Address.
- **Meter Model** A constant identifying the product range (MultiCube=100).
- **Meter Type** (1 – 6). Refer to MultiCube manual for details of meter types.
- **Meter Software** MultiCube version (e.g. 0x0014 = Version 1.04).
- **V/I MD Period** (1-255) Time period (seconds/10) for Current and Voltage Demand. Eg. A value of 6 corresponds to a demand period of 60 seconds.

* kVAh Pulsing may replace kvarh in some MultiCubes.

4.5.7 Table 15 Peak Current and Voltage Demand

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|------------|--------------|-------|-------|-------------------------|
| 0 | 3840 | Peak I1 MD | unsigned Int | 2 | 1 | Read/Write ⁵ |
| 1 | 3841 | Peak I2 MD | unsigned Int | 2 | 1 | Read/Write ⁵ |
| 2 | 3842 | Peak I3 MD | unsigned Int | 2 | 1 | Read/Write ⁵ |
| 3 | 3843 | Peak V1 MD | unsigned Int | 2 | 1 | Read/Write ⁶ |
| 4 | 3844 | Peak V2 MD | unsigned Int | 2 | 1 | Read/Write ⁶ |
| 5 | 3845 | Peak V3 MD | unsigned Int | 2 | 1 | Read/Write ⁶ |

- Notes:**
5. Use 'Amps Scale' at Addr 2837 to convert to real Peak Amp Demand.
 6. Use 'Ph Volts Scale' at Addr 2838 to convert to real Peak Volts Demand.

The peak values of rolling demand averages of currents and voltages are available in Table 15 as unsigned integers.

4.5.8 Table 16 Current and Voltage Demand

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|-----------|--------------|-------|-------|------------------------|
| 0 | 4096 | I1 Demand | unsigned Int | 2 | 1 | Read Only ⁵ |
| 1 | 4097 | I2 Demand | unsigned Int | 2 | 1 | Read Only ⁵ |
| 2 | 4098 | I3 Demand | unsigned Int | 2 | 1 | Read Only ⁵ |
| 3 | 4099 | V1 Demand | unsigned Int | 2 | 1 | Read Only ⁶ |
| 4 | 4100 | V2 Demand | unsigned Int | 2 | 1 | Read Only ⁶ |
| 5 | 4101 | V3 Demand | unsigned Int | 2 | 1 | Read Only ⁶ |

- Notes:**
5. Use 'Amps Scale' at Addr 2837 to convert to real Amp Demand.
 6. Use 'Ph Volts Scale' at Addr 2838 to convert to real Volts Demand.

The rolling demand averages of currents and voltages are available in Table 16 as unsigned integers.

Note: Tables 15 and 16 are only available in MultiCube meters with software versions 1.04 or later. An invalid table exception will be returned on earlier meters.

Modbus Communication

4.5.9 Table 17 Voltage and Current Distortion

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|----------|--------------|-------|-------|-------------------------|
| 0 | 4352 | V1 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |
| 1 | 4353 | V2 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |
| 2 | 4354 | V3 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |
| 3 | 4355 | I1 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |
| 4 | 4356 | I2 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |
| 5 | 4357 | I3 THD | unsigned Int | 2 | 1 | Read Only ¹¹ |

Notes: 11. THD values are scaled as 0 - 999 representing 0 – 99.9%

4.5.10 Table 18 Power Maximum Demand

| Offset | Address | Contents | Format | Bytes | Words | Access |
|--------|---------|--------------|--------------|-------|-------|--------------------------|
| 0 | 4608 | kW MD | unsigned Int | 2 | 1 | Read Only ¹² |
| 1 | 4609 | kVA MD | unsigned Int | 2 | 1 | Read Only ¹² |
| 2 | 4610 | kvar MD | unsigned Int | 2 | 1 | Read Only ¹² |
| 3 | 4611 | Peak kW MD | unsigned Int | 2 | 1 | Read/Write ¹² |
| 4 | 4612 | Peak kVA MD | unsigned Int | 2 | 1 | Read/Write ¹² |
| 5 | 4613 | Peak kvar MD | unsigned Int | 2 | 1 | Read/Write ¹² |

Notes: 12. All MD & Peak MD values in Table 18 are scaled as 3-Phase kW/10

13. kW MD and Peak kW MD are also mapped in Table 13.

Note: Tables 17 and 18 are only available in MultiCube Type 6 meters. An invalid table exception will be returned on other meters.

RTU Commands

4.5.11 Function 04 (or 03) Read Multiple Registers

Description

This function allows a number of registers from a meter table to be read in a single operation. This command is commonly used to obtain instantaneous, energy or set-up data from the meter. This command is not available as a *broadcast* command as it requires a return data packet from the meter.

Host Request

| | BYTE | EXAMPLE |
|----------------------------------|------|---------|
| METER ADDRESS | 1 | 19H |
| FUNCTION | 2 | 04H |
| TABLE NUMBER (Address High Byte) | 3 | 0BH |
| TABLE OFFSET (Address Low Byte) | 4 | 00H |
| No. OF WORDS (N) (High Byte) | 5 | 00H |
| No. OF WORDS (N) (Low Byte) | 6 | 03H |
| CHECKSUM (High Byte) | 7 | B1H |
| CHECKSUM (Low Byte) | 8 | F7H |

The example above shows a read of 3 consecutive Integers from the Instantaneous Data Table 11(0BH), offset 0. The meter accessed has a Modbus ID of 25 (19H).

Modbus Communication

Meter Response

| | BYTE | EXAMPLE |
|-----------------------------|------|---------|
| METER ADDRESS | 1 | 19H |
| FUNCTION | 2 | 04H |
| NUMBER OF BYTES (2N) | 3 | 06H |
| DATA REGISTER 1 (High Byte) | 4 | 02H |
| DATA REGISTER 1 (Low Byte) | 5 | 3AH |
| DATA REGISTER 2 (High Byte) | 6 | 07H |
| DATA REGISTER 2 (Low Byte) | 7 | 5CH |
| DATA REGISTER N (High Byte) | 8 | 07H |
| DATA REGISTER N (Low Byte) | 9 | 02H |
| CHECKSUM (High Byte) | 10 | 51H |
| CHECKSUM (Low Byte) | 11 | E3H |

The example shows a reply of 6 bytes (3 Integers) as:

3-Ph kW = 570 (02 3A Hex)
3-Ph kVA = 1884 (07 5C Hex)
3-Ph kvar = 1794 (07 02 Hex)

4.5.12 Function 06 Preset a Single Register

Description

This function allows a single integer register in a meter table to be changed by the host. This command is commonly used to program meter parameters or to reset energy registers to zero. When broadcast (address=0) all meters on the network are addressed together but none reply.

Host Request

| | BYTE | EXAMPLE |
|----------------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 06 H |
| TABLE NUMBER (Address High Byte) | 3 | 0E H |
| TABLE OFFSET (Address Low Byte) | 4 | 00 H |
| DATA VALUE (High Byte) | 5 | 00 H |
| DATA VALUE (Low Byte) | 6 | C8 H |
| CHECKSUM (High Byte) | 7 | 89 H |
| CHECKSUM (Low Byte) | 8 | 6C H |

The example above shows a value of 200 (00H C8H) written to the CT Primary register (Data Table 14, offset 0). The meter accessed has a Modbus ID of 25 (19H).

Modbus Communication

Meter Response

| | BYTE | EXAMPLE |
|----------------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 06 H |
| TABLE NUMBER (Address High Byte) | 3 | 0E H |
| TABLE OFFSET (Address Low Byte) | 4 | 00 H |
| DATA VALUE (High Byte) | 5 | 00 H |
| DATA VALUE (Low Byte) | 6 | C8 H |
| CHECKSUM (High Byte) | 7 | 89 H |
| CHECKSUM (Low Byte) | 8 | 6C H |

The reply format is a copy of the command confirming its validity:

NOTE: This Modbus command is limited to writing 2-byte data only. Long Integer registers may be written but the meter assumes sets upper bytes automatically to zero.

4.5.13 Function 08 Loop Back Diagnostic

Description

This function provides a simple means of testing the communication network and detecting if a particular meter is present. This command is not available as a *broadcast* command as it requires a return data packet from the meter.

Host Request

| | BYTE | EXAMPLE |
|-----------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 08 H |
| DIAGNOSTIC CODE (High Byte) | 3 | 00 H |
| DIAGNOSTIC CODE (Low Byte) | 4 | 00 H |
| DIAGNOSTIC DATA (High Byte) | 5 | 03 H |
| DIAGNOSTIC DATA (Low Byte) | 6 | E8 H |
| CHECKSUM (High Byte) | 7 | E3 H |
| CHECKSUM (Low Byte) | 8 | 6D H |

The example above shows a command with a Loop Back Code of 0 and Diagnostic Data of 1000 (03H E8H). The meter accessed has a Modbus ID of 25 (19H).

Modbus Communication

Meter Response

| | BYTE | EXAMPLE |
|-----------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 08 H |
| DIAGNOSTIC CODE (High Byte) | 3 | 00 H |
| DIAGNOSTIC CODE (Low Byte) | 4 | 00 H |
| DIAGNOSTIC DATA (High Byte) | 5 | 03 H |
| DIAGNOSTIC DATA (Low Byte) | 6 | E8 H |
| CHECKSUM (High Byte) | 7 | E3 H |
| CHECKSUM (Low Byte) | 8 | 6D H |

The reply format is a copy of the command confirming its validity:

4.5.14 Function 16 Preset Multiple Registers

Description

This function allows a number of registers in a meter table to be set, by the host, in a single operation. When broadcast (address=0) all meters on the network are addressed together but none reply.

Host Request

| | BYTE | EXAMPLE |
|--------------------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 10 H |
| TABLE NUMBER (Address High Byte) | 3 | 0D H |
| TABLE OFFSET (Address Low Byte) | 4 | 03 H |
| NUMBER OF DATA WORDS (N) (High Byte) | 5 | 00 H |
| NUMBER OF DATA WORDS (N) (Low Byte) | 6 | 03 H |
| NUMBER OF DATA BYTES (2N) | 7 | 06 H |
| DATA BYTE 1 | 8 | 00 H |
| DATA BYTE 2 | 9 | 00 H |
| DATA BYTE 3 | 10 | 00 H |
| DATA BYTE 4 | 11 | 00 H |
| DATA BYTE 5 | 12 | 00 H |
| DATA BYTE 6 | 13 | 00 H |
| CHECKSUM (High Byte) | 14 | 0C |
| CHECKSUM (Low Byte) | 15 | FB |

The example above simultaneously writes 00 to all three peak hold voltage registers (V1 Peak Hold = Table 13, Offset 3). The meter accessed has a Modbus ID of 25 (19H).

Modbus Communication

Meter Response

| | BYTE | EXAMPLE |
|----------------------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 10 H |
| TABLE NUMBER (Address High Byte) | 3 | 0D H |
| TABLE OFFSET (Address Low Byte) | 4 | 03 H |
| NUMBER OF DATA WORDS (High Byte) | 5 | 00 H |
| NUMBER OF DATA WORDS (Low Byte) | 6 | 03 H |
| CHECKSUM (High Byte) | 7 | 71 H |
| CHECKSUM (Low Byte) | 8 | 7C H |

The reply confirms the data address and amount of data received.

4.5.15 Exception Responses

When a host sends a query to an individual meter on the network it expects a normal response. In fact one of four possible events may occur as a result of the query:

- ◇ If the Options Unit receives the message with no communication errors, and can handle the query it will reply with a normal response.
- ◇ If the Options Unit does not receive the message due to a communication failure, no response will be returned and the host will eventually time-out.
- ◇ If the Options Unit receives the message but detects a communication error via its CRC, no response will be returned and the host will time-out.
- ◇ If the Options Unit receives the query with no communication errors but cannot handle the query (out of range data or address) the response will be an **Exception Response** informing the host of the nature of the error.

An Exception Response differs from a normal response in its Function Code and Data Fields.

Exception Response

| | BYTE | EXAMPLE |
|----------------------|------|---------|
| METER ADDRESS | 1 | 19 H |
| FUNCTION | 2 | 84 H |
| EXCEPTION CODE | 3 | 02 H |
| CHECKSUM (High Byte) | 4 | 42 H |
| CHECKSUM (Low Byte) | 5 | C6H |

Modbus Communication

EXCEPTION FUNCTION CODE

All normal function types have a most significant bit of 0 (< 80 Hex). In an Exception Response the meter sets the MSB to 1 (adds 80H to the received Function Type). The Function can therefore be used by the host to detect an Exception Response.

DATA FIELD

In an Exception Response the data field is used only to return the type of error that occurred (*Exception Code*).

The MultiCube Options Unit utilises the following Exception Codes:

| Code | Meaning |
|------|--|
| 1 | Data out of range |
| 2 | Table and/or offset out of range for this function |
| 3 | Odd number of Integers written to Long Integer registers |
| 9 | Communications from Option Module to meter has failed |

4.6 Modbus Diagnostics LEDs

The MultiCube Option units use 3 LEDs to aid commissioning into a Modbus system. These indicators are also useful to check continued operation of the device.

The LEDs are intelligent indicators, which are illuminated under specific conditions as follows:

- VALID COMMAND** **'Cmd'** - Illuminated when a host command is received, surrounded by RTU frame breaks (ref 4.4.2) with the correct Modbus address.
- ERROR/EXCEPTION** **'Err'** - Illuminated when a Valid Command is received as above but a CRC Error (ref 4.4.2) or Exception Condition (ref 4.5.15) is detected.
- BUS ACTIVITY** **'Bus'** - Illuminated whenever changes occur on the receive input pins of the module.

Specification

5. Specification

| Auxiliary Supply (Retro-Fit Options Module) | |
|--|---|
| Option Module | 230vac or 110vac 50/60Hz ±15% Automatic voltage selection when inserted into MultiCube MultiCube MUST be rated to match either selection. |
| Load | 3 VA Maximum |
| Isolation | 2.5 kV (Supply internally wired to meter auxiliary mains inputs) |

| Modbus Serial Comms | |
|--|---|
| Bus Type RX Loading TX Drive | RS422 / RS485 4/2 Wires + 0V. Half Duplex 1/4 Unit Load Per Options Unit 32 Unit Loads |
| Protocol | Modbus RTU with 16 bit CRC. (JBUS compatible) |
| Baud Rate | 4800, 9600 or 19200 user programmable |
| Address | User Programmable 1-247 |
| Reply Time Max Data Packet Command Rate | 100ms maximum from command end to reply start Any complete Table (Energy, Instantaneous, set-up etc) New command within 5ms of previous one |

| Mechanical (Retro-Fit Options Module) | |
|--|---|
| Enclosure | Custom Options Enclosure. Material Mablex UL94-V-0 |
| Options Unit Unfitted MultiCube + Options | W=87mm x H=59mm x L=75mm W=96mm x H=96mm x L= 138mm (130mm behind panel) |
| Weight | Approx. 200g |
| Terminals | Rising Cage. 0.2 - 4.0mm ² Conductors |

| General | |
|--|--|
| Operating Temperature Storage Temperature | -10 deg C to +65 deg C -25 deg C to +70 deg C |
| Environment | IP40 (Retro-Fit Options Unit) |
| Humidity | <75% non-condensing |

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