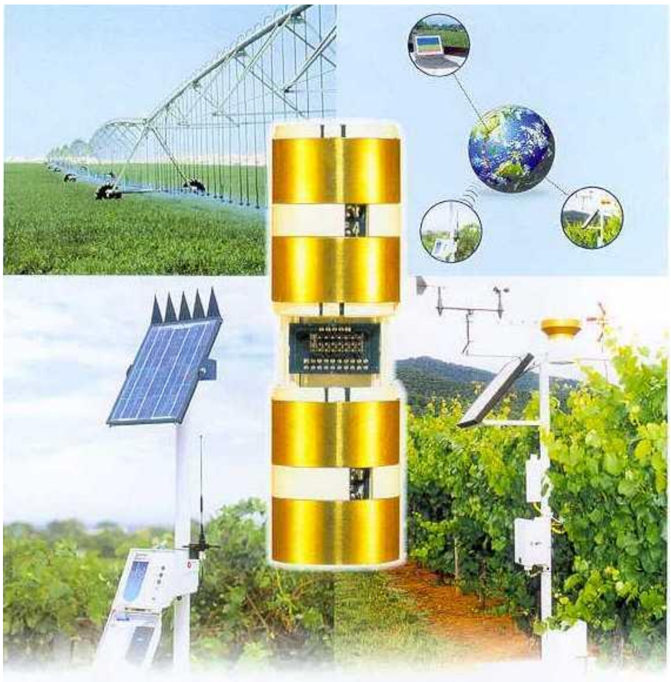
RS232/485 MODBUS



Hardware Manual

Version 3.6

For firmware revision 1.2.3 and above)

Details of the Modbus specification can be obtained from "The Modbus Organization" at www.modbus.org

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Modbus Rev 3.6 (2014-12-23)

Statements of Compliance

FCC note of compliance and statement of liability

Electro-Magnetic Compliance

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorientation or relocation of the receiving antenna.
- Connection of the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consultation with the dealer or an experienced radio/TV technician.

EMC approvals

The EnviroSCAN 232/485 and EasyAG 232/485 Series II probes comply with standard "EN61326:1997 Amendment 1:1998, Amendment 2:2001, Amendment 3:2003 EMC standard for equipment for measurement, control and laboratory use”

The equipment complies with the following specifications:

- EN55011: 1998, Amendment 1: 1999 Radiated and conducted emissions
- EN61000-4-2: 1995 Immunity to Electrostatic Discharge (ESD)
- EN61000-4-3: 2002 Immunity to Radiated Fields (RF)
- EN61000-4-4: 1995 Immunity to Electrical Fast Transients (EFT)/ Bursts
- EN61000-4-5:1995 Immunity to Surges
- EN61000-4-6:1996 Immunity to Conducted RF
- FCC Part 15 Class B

The Sentek Drill & Drop system complies with the following specifications;

- FCC Part 15 Subpart B
  Radio Frequency Devices – Unintentional Radiators
- CISPR 11:2010 Ed 5.1
  Industrial Scientific and Medical (ISM) radio-frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement
- IEC 6132601:2012 Ed 2
  Electrical equipment for measurement, control and laboratory use – EMC requirements. Part 1: General requirements.
- RoHS EN 50581:2012
  Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances.

Marking

The above EMC approvals allow the product to be marked CE, C-tick and FCC.

Modifications

Any modifications to any part of the equipment or to any peripherals may void the EMC compliance of the equipment.

Radio Interference

The probe is not to be operated in free air as it may cause interference to radio communication devices

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The Sentek MODBUS Probe Interfaces

This section provides information about Sentek EnviroSCAN Modbus, EasyAG Modbus and Drill & Drop Modbus probe interfaces.

Caution:
Modbus interface firmware version 1.4.1 or later is required to use Drill & Drop probes or EnviroSCAN temperature and humidity sensors. Earlier versions 1.2.3 to 1.3.x firmware only supports moisture and salinity sensors.

References

- Sentek TriSCAN™ Agronomic User Manual
- Sentek Drill & Drop Probe Manual
- Sentek Calibration Manual
- Sentek Probe Configuration Utility User Guide
- Modicon Modbus™ Protocol Reference Guide, PI-MBUS-300 Rev J, June 1996
  www.modbus.org

Modbus probe interfaces

Modbus probe interfaces are used to allow an RS485 or RS232 - Modbus compatible device to communicate with and retrieve data from multiple Sentek sensors.

The Modbus probe interfaces behave as a slave (DTE – Data Terminal Equipment) device, meaning it only responds to requests from a Modbus master (DCE – Data Communication Equipment) device. When instructed to sample data, the probe interface will retrieve values from each sensor configured on the probe. These values are returned to the Modbus master device upon request.

There are three variants of probe type; EnviroSCAN, EasyAG and Drill & Drop. The EnviroSCAN probe has user configurable sensor depths and can be installed to great depths. The EasyAG is a smaller diameter probe, compared to the EnviroSCAN, and is more suited to shallow rooted crops and short term applications. Both have an interface card at the top which reads the sensors and provides the Modbus communication (when Sentek Modbus firmware is installed). Drill & Drop probes have encapsulated sensors and encapsulate interface box.

The probe and its sensors are configured using the Probe Configuration Utility software.

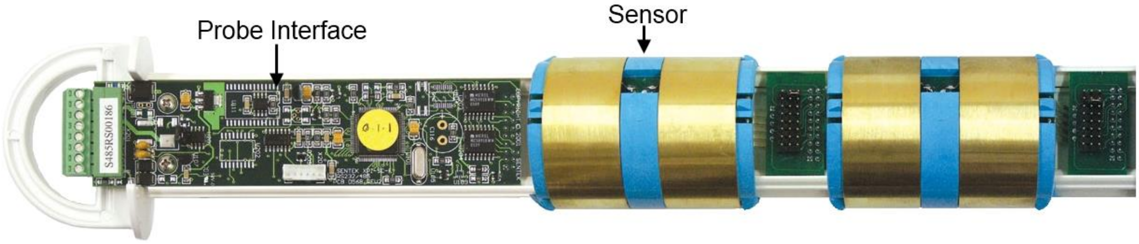

Figure 1 EnviroSCAN probe

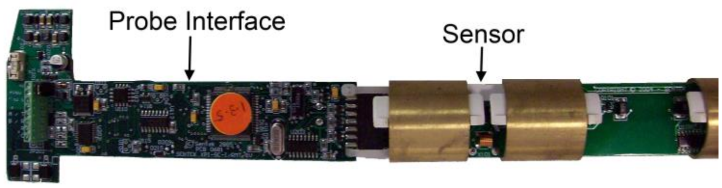

Figure 2 EasyAG probe

Figure 3 Drill & Drop probe interface and sensor rod

Figure 3 Drill & Drop probe interface box

Probe Configuration Utility

The Probe Configuration Utility is used to configure the Modbus probe interfaces with sensor depth location, normalization values (air and water counts) and calibration information for each sensor installed on the probe. This information is stored in non-volatile memory on the probe interface, and is used to produce the calculated value (value that has been processed via the interfaces calibration formula) from each sensor on the probe.

Communication between the Probe Configuration Utility and the Modbus probe interface is done using the **EnviroSCAN/EasyAG** Probe Configuration Utility cable, or Drill & Drop Probe Configuration Utility cable, from a computer's communication port to the probe interface's TTL port.

- **EnviroSCAN** interfaces now support optional Temperature and Humidity sensors in addition to moisture and salinity sensors.
- **EasyAG** interfaces only support moisture and salinity sensors.
- **Drill & Drop** probes include temperature sensors in addition to moisture and salinity sensors.

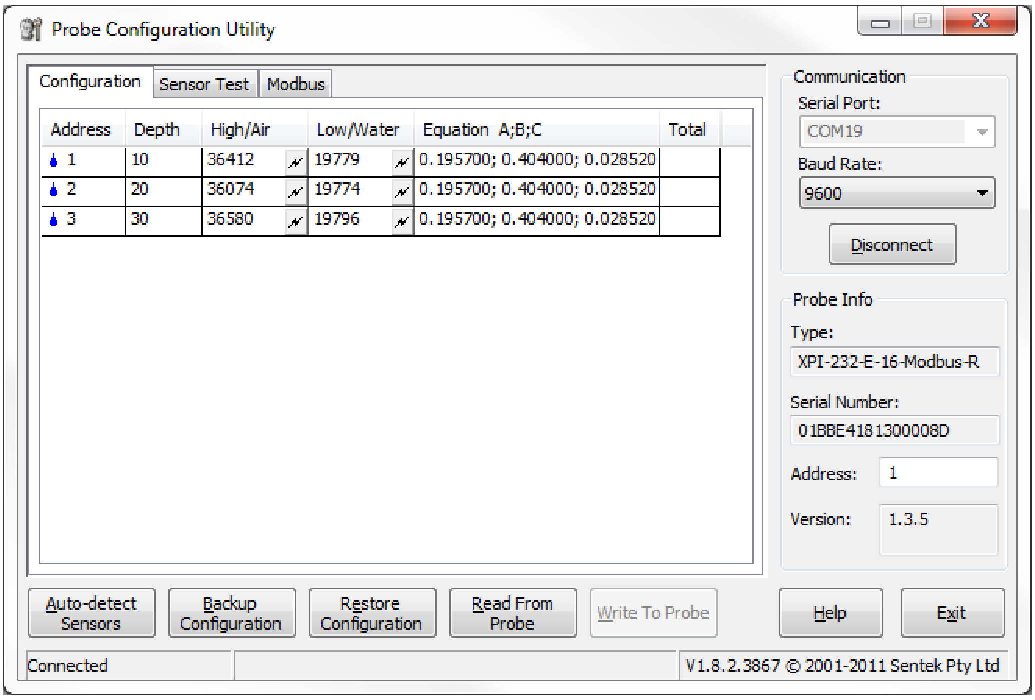

Figure 3 Probe Configuration Utility software

Setting up the probe interface

The Probe Configuration Utility is provided to configure Modbus probe interfaces with depth location, normalization values (air and water counts) and calibration.

Note: Drill & Drop probes come fully configured and normalised so only the Modbus communication mode and Modbus address may need to be changed.

The probe interface must be fully configured before sensors can be read through the Modbus output. The sections below describe each of the areas of configuration on a Sentek Modbus interface.

Why do I need to configure the probe interface?

The Modbus probe interface must be configured to ensure valid information is reported to the Modbus master device when data is requested. This information includes the number, depth and type of sensors, normalization values (air and water counts), calibration information and Modbus communication parameters.

Warning:

Incorrect configuration information stored in the Modbus probe interface will result in incorrect calculated readings being reported to the Modbus master device.

For more information on setting up the Modbus probe interface, refer to the Probe Configuration Utility online help.

Configuration Page

Note: Drill& Drop probes are preconfigured with depths starting at 5cm and are pre-normalised. A Backup Configuration should be done before changing these pre-set values.

Auto-detect Sensors will detect all sensors currently installed on the probe. After the sensors are detected the configuration information (including type of sensor) will be displayed in the Probe Configuration list.

After Auto-detecting sensors, the sensor depths need to be entered in the **Depth** Column.

Maximum (air) and minimum (water) sensor values, within a Sentek access tube, need to be obtained and saved in the probe. This process is called normalization and is explained in Sentek Distributor training documents. The normalization process is necessary to adjust for any variances that may occur during the production of the sensor.

The **Equation** column is used to store A, B and C coefficients used in the calibration equation, which determines the final value output by the interface. The coefficients are entered in A, B then C order, separated by semicolons. See the Sentek Calibration Manual for more information.

Setting the Modbus Address

The Modbus address for the probe can be set in the **Address** field on the right hand side of the PConfig screen. The address of the probe should be in the range “1” to “247”.

Changing the Modbus Port Settings

The **Sentek** Probe Configuration Utility is used to configure probe address, sensor settings, and the Modbus communication settings. The default settings are RTU mode, 9600 baud, no parity, and 500ms turn-around time (see section *Turn-around time*). Each field is described in the Probe Configuration Utility Help file.

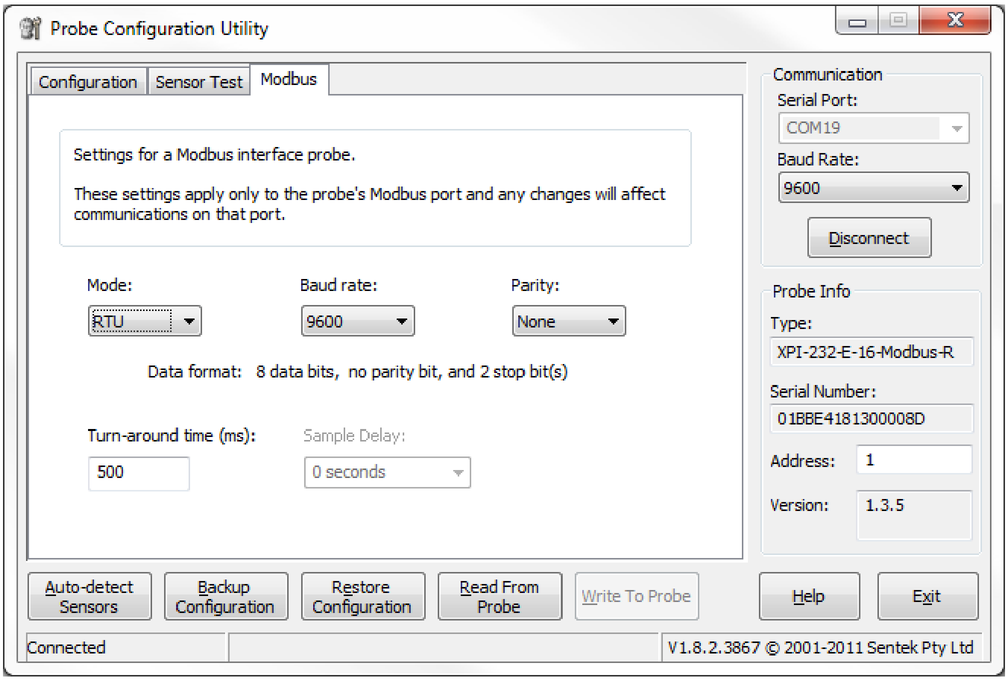

Figure 4 Modbus Configuration Page

Modbus Communication

About the Modbus Communication

The **Sentek** implementation of the Modbus protocol allows sampling of **Sentek** sensors, either all or selected, and the recovery of calculated values.

The implementation is based on the document “Modicon Modbus Protocol Reference Guide” PI-MBUS-300 Rev J. This document is available at www.modbus.org.

The Modbus Protocol

The Modbus protocol is a master/slave command protocol in which the master sends a query packet to the slave, which performs the requested operation and responds.

Probe interfaces can be configured to support either RTU mode or ASCII mode.

RTU Mode

RTU Mode is a binary mode with 8-bit data bytes being transmitted. Each transmitted byte is in fact 11 bits, consisting of one start bit, 8 data bits, an optional parity bit, and either one (if parity is used) or two (if no parity) stop bits. Parity may be selected as even or odd.

Each query packet from the master consists of a device address (one byte), function code (one byte), optionally one or more 8-bit data bytes, and an error check CRC (two bytes). The packet is delimited by timing, where at least 3.5 characters of silence must precede the start of the packet. No more than 1.5 character times are permitted between characters in the packet, and the packet terminates on at least 3.5 character times of silence.

Start	**Address**	**Function**	**Data**	**CRC**	**End**
T1-T2-T3-T4	8 bits	8 bits	*n* x 8 bits	16 bits	T1-T2-T3-T4

Figure 5 RTU message frame

ASCII Mode

ASCII Mode packets consist of readable characters with 7-bit data bytes being transmitted. Each transmitted byte is in fact 10 bits, consisting of one start bit, 7 data bits, an optional parity bit, and either one (if parity is used) or two (if no parity) stop bits. Parity may be selected as even or odd.

The actual packet data in ASCII mode is the same as for RTU except for the error check and each byte being coded as two ASCII hexadecimal digits. A Packet commences with a colon (“:”) character and is terminated with a <CR><LF> pair, with up to 1 second permitted between characters within a packet. In ASCII mode, the error check consists of a two-character “Longitudinal Redundancy Check” formed by adding all characters (starting with the address byte) and forming the twos complement. The lower byte of the sum is encoded as two hexadecimal characters.

ASCII mode transfers data at about 50% of the speed of RTU mode, but has the advantage of being less timing sensitive, and in addition it is easy to capture and decode the packets.

Start	**Address**	**Function**	**Data**	**LRC**	**End**
1 char (‘:’)	2 chars	2 chars	*n* chars	2 chars	2 chars (<CR><LF>)

Figure 6 ASCII message frame

Turn-around time

Turn-around time applies only to RS485 devices or half-duplex radio devices on RS232.

The turn-around time is the minimum time, in milliseconds, before the probe will start sending the response (maximum 1000 ms, minimum 0 ms, default 500ms). The actual minimum is dependent on the time required for the probe to process the request.

The probe turn-around time must be set higher than the time it takes the master device to switch from Tx to Rx. Failure to do so may result in the probe transmitting data before the master device is ready to receive data, resulting in loss of data. The master device must be ready to receive data once the turn-around time has elapsed.

Note: This field is disabled if the probe firmware version does not support turn-around time.

Modbus Overview

The Modbus protocol models the interface as a set of 16-bit registers that can be read or written by a Modbus master device.

Note: An attempt to read or write register numbers outside the supported ranges will result in a command being rejected with 'Illegal data address'.

Note: Input registers and Holding registers are stored in volatile memory and will be lost when power is removed from the probe interface. Some registers are restored at power on.

Input Registers

These are read-only registers. The Sentek Pty Ltd probe interface supports input registers 30001-30026, 30100, 30101-30228 and 30257-30480.

Note: Firmware before version 1.4.1 limits the input register ranges to 30001-30018, 30100, 30101-30164 and 30257-30384 (no temperature or humidity sensors). Some of these registers were reserved for future use, and if read will respond with zero.

Holding Registers

These are registers that can be read and written. The Sentek Pty Ltd probe interface supports holding registers 40001-40009.

Note: Firmware before version 1.4.1 limits the holding register range to 40001-40005.

Note: When writing to multiple Holding Registers, the higher address registers are written to first, this permits a single write to set the mask and initiate the reading process.

Sleep Mode

The Modbus probe interface will enter into sleep mode after 15 seconds of inactivity on either the TTL Communications port, or the RS232/RS485 port. The interface will wake when any communication is received to either port.

Note: Communication received whilst the interface is in sleep mode, will not be recognized as a valid command. The master device will need to retry any communication that may wake the interface.

The probe will respond to Modbus commands 1 second after power on.

Commands

A Modbus query can set the values of one or more Holding Registers, or interrogate the values of one or more Input or Holding Registers. For example, the command (in ASCII mode)

:01 03 00 00 00 02 FA

requests the reading of Holding Registers 40001 through 40002 from probe 1, while

:00 06 00 00 00 02 F8

is a broadcast command (i.e. has a slave address of zero) that will preset Holding Register 40001 to the value 2, which will start a scan of all moisture sensors. As the results become available, they are stored in Input Registers starting at 30257, with two consecutive 16-bit registers holding a single floating point (32-bit) value, high bytes being stored in the lower address.

Broadcast Commands

Commands sent with a slave address of 00 are Broadcast Commands. In a multi-drop environment (RS-485) all connected slaves will receive the command, but make no response.

Modbus Commands

The probe interface supports the following subset of Modbus commands:

Caution:
Modbus interface firmware version 1.4.1 or later is required to access temperature or humidity input registers and holding registers.

Function Code	Name	Notes	Broadcast
03 (0x03)	Read Holding Registers	Status of measurement process Maximum of 9 in one read	No
04 (0x04)	Read Input Registers	Selections of sensors, cooked data, configuration of sensors Maximum of 32 in one read	No
06 (0x06)	Preset Single Register	Control measurement process	Yes
08 (0x08)	Diagnostic	Subfunctions: 0 - return query data 1 - restart communications 3 - Change ASCII input delimiter	No
11 (0x0B)	Fetch Comm Event Counter		No
16 (0x10)	Preset Multiple Holding Registers	Maximum of 9 in one write	Yes
17 (0x11)	Report Slave ID		No

Figure 7 Implemented Functions

In reading and presetting multiple holding registers, a maximum of 9 registers can be read or set with a single command. A maximum of 32 input registers can be read with a single command because of limits in maximum command/response length supported by the probe interface.

Read Holding Registers

Note: This example, and the following examples show the command in ASCII mode. Other modes have equivalent structure except for the checksum value,

The command

:01 03 00 00 00 02 FA

is parsed as

01 Slave Address
03 Command - Read Holding Registers
00 00 Address; add 40001 to get the absolute address
00 02 Number of registers
FA LRC

The slave will respond with a packet such as

:01 03 04 01 03 02 77 7B

which is to be interpreted as

01 Slave Address
03 Function code
04 Data byte count
01 03 Contents of 40001
02 77 Contents of 40002
7B LRC

A maximum of 9 registers can be requested at once. There is no response in broadcast mode.

Read Input Registers

The command

:01 04 00 02 00 03 F6

is parsed as

01	Slave Address
04	Command - Read Input Registers
00 02	Address; add 30001 to get the absolute address
00 03	Number of registers
F6	LRC

The response is similar to that for a Read Holding Registers command.

A maximum of 32 registers can be requested at once. There is no response in broadcast mode.

Preset Single Holding Register

The command

:01 06 00 00 00 02 F8

is parsed as

01	Slave Address
06	Command - Preset Single Registers
00 00	Address; add 40001 to get the absolute address
00 02	16 bit data value
F7	LRC

The response is an echo of the command. There is no response in broadcast mode, but the register is updated and the requested action performed.

Preset Multiple Holding Registers

This command allows up to 9 Holding Registers to be preset.

:01 10 00 00 00 03 06 11 11 22 22 33 33 1A

is parsed as

01	Slave Address
10	Command: Preset Multiple Registers
00 00	Address - Add 40001 to get absolute address
00 03	Register Count
06	Data Byte Count
11 11	New Value of 40001
22 22	new Value of 40002
33 33	New Value of 40003
1A	LRC

The response is the “header” part of the command

01 10 00 00 00 03 EC

which is interpreted as

01	Slave Address
10	Function Code
00 00	Address
00 03	Register Count
EC	LRC

Note: In writing to multiple Holding Registers, the higher address registers are in fact written to first; this permits a single write to both set the mask and initiate a reading.

There is no response in broadcast mode, but the registers are updated and the requested action is performed.

Diagnostic Command

The following sub-commands are supported by the Modbus probe interface.

Return Query Data

This command is simply echoed back to the Master

:01 08 00 00 A5 37 1B

is parsed as

01	Slave Address
08	Command - Diagnostic
00 00	Subfunction: Return Query Data
A5 37	Data
F6	LRC

This is simply a request to echo the data; the response should be identical to the command.
Note that the response data is always two bytes long.

Restart Communications Option

This command causes a power on reset of the communication interface. All event counters are reset by this function.

:01 08 00 01 00 00 F6

is parsed as

01	Slave Address
08	Command - Diagnostic
00 01	Subfunction: Restart Communications
00 00	Data must be either 0000 or FF00
F6	LRC

The response is sent before the reset and is identical to the command. There is no response in broadcast mode. In either case the Modbus subsystem is reinitialized as if the device was power cycled:

- Clears measurement status
- Clears sensor selection mask
- Clears scanned sensors mask
- Clears diagnostic counters
- Resets ASCII input delimiter to <LF> (not reset by power cycling)

Change ASCII Input Delimiter

Normally, in ASCII mode, a command/reply is terminated with <CR><LF>. There may be cases where the <LF> character causes problems in communication, and it can be changed (but not the <CR>) using diagnostics sub-function 3.

:01 08 00 03 58 00 9C

is parsed as

01	Slave Address
08	Command - Diagnostic
00 03	Subfunction: Change Delimiter
58 00	Data: Delimiter is 0x58 (“X”)
9C	LRC

The <LF> delimiter (for both received and transmitted data) will now be “<CR>X”; the response is sent after the change and is identical to the command. Any character (00 to FF) can be set as the delimiter; the second (low) data byte must be zero, or the command will be rejected with an Invalid Data exception.

This command should be used with care, because once changed the probe will no longer respond to commands terminated with <CR><LF>. The only way to change it back in ASCII mode is a new command with the correct delimiter; alternatively, the probe can be changed to RTU mode and a new delimiter set.

The delimiter is not reset by removing power from the probe, but is reset by Diagnostic sub-function 1 (Restart Communications Option).

Fetch Comm Event Counter

This returns a count of successfully executed queries since the probe interface was last powered on or reset.

:01 0B F4

is parsed as

01 Slave Address
0B Command - Fetch Event Counter
F4 LRC

The response might be

01 0B FF FF 01 08 ED

which is interpreted as

01 Slave Address
0B Function Code
FF FF Status: Slave is busy measuring
01 08 Message Count
F4 LRC

The status word is FFFF if the slave is in the process of taking a measurement, else 0000.

There is no response in broadcast mode.

Report Slave ID

This requests information about the slave.

:01 11 EE

is parsed as

01 Slave Address
11 Command - Report Slave Id
EE LRC

The response might be

:01 11 14 00 FF 53 45 4E 54 45 4B 01 00 00 01 10 D1 7A 0F 00 08 00 34 6F

which is interpreted as

01 Slave Address
11 Function Code
14 Byte Count
00 Slave ID (always 00)
FF Run Indicator (always FF)
53 45 4E 54 45 4B "SENTEK"
01 00 00 01 Revision Code (1.0.01)
10 D1 7A 0F 00 08 00 34 Probe Serial Number
6F LRC

There is no response in broadcast mode.

The revision code is interpreted as

01 Major Revision

00 Minor Revision

00 01 Sub-minor Revision (2 bytes, most significant first)

Exception Responses

Illegal commands result in an exception response. The reply has the top bit of the Function Code set, and contains a one-byte exception code.

:01 81 01 7D

which is interpreted as

01	Slave Address
81	Function Code - Exception
01	Exception Code (Illegal Function)
7D	LRC

Exception codes are

1	Illegal Function
2	Illegal Data Address
3	Illegal Data Value
6	Slave Busy

Note: An exception response with exception code = 2 will occur for any address not described in the register map section.

Register Map

This table shows all of the registers available through the Sentek Modbus interface.

Address	Description
30001	Last measurement command
30002	Measurement status
30003-30020	Sensor masks for selected, detected and scanned (moisture, salinity and temperature)
30021-30026	Sensor masks for selected, detected and scanned (humidity)
30100	Number of Sensors (32)
30101-30228	Sensor depths (32 each, type moisture, salinity. Temperature and humidity)
30257-30480	Each sensors cooked value (32 each type, moisture, salinity. Temperature and humidity)
40001	Measurement command
40002-40009	Sensor selection mask for the command (2 words each type, moisture, salinity. Temperature and humidity)

Note: Although the register map supports up to 32 sensors for each type, at present Sentek probes have maximum of 16 sensors per sensor type. Consequently the second word of each sensor mask is not currently used.

Input Registers

Caution:

- The three humidity sensor masks (30021-30026) are consecutive rather than following each temperature sensor mask.
- All sensor registers are stored in ascending sensor address (sensor number).

Absolute Address	Relative Address	Description
30001	0x0000	Last measurement selection This register is updated with the value from holding register 40001 when the measurement is started. It remains this value after the measurement is completed.
30002	0x0001	Measurement Status 0 - No measurement 1 - Measurement in progress 2 - Measurement completed, with no errors 3 - Measurement completed, but errors occurred An error means a sensor failed during reading or no configured sensors were selected for sampling (sensors with a depth of zero are not configured). The cooked data will have IEEE Not-a-number in the failing sensor(s). Note that Not-a-number also occurs if the raw to cooked calculation produces a value outside the valid range.

Absolute Address	**Relative Address**	**Description**
Sensors Scan Selection Masks (moisture, salinity, temperature, humidity) These registers specify which sensors will be scanned when 40001 is set to 1 (measure selected sensors). These registers are set using the sensor selection mask from holding registers 40002 to 40008. The bits in this mask are in the same order as the detected sensor mask.		
30003 – 30004	0x0002	**Moisture** Sensor Selection for current scan (Bit 0 is first moisture sensor, Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
30005 – 30006		**Salinity** Sensor Selection for current scan (Bit 0 is first salinity sensor, Bit 1 is second salinity sensor, … Bit 16 is 17th sensor, etc)
30007 – 30008		**Temperature** Sensor Selection for current scan (Bit 0 is first temperature sensor, Bit1 is second temperature sensor, … Bit 16 is 17th sensor, etc)
30021 – 30022		**Humidity** Sensor Selection for current scan (Bit 0 is first sensor, Bit 1 is second sensor, … Bit 16 is 17th sensor, etc) **Caution:** this humidity mask is not the consecutive address after the temperature mask
Detected (and configured) Sensors Mask (moisture, salinity, temperature, humidity) The bits in this mask are in sensor address order. Un-configured sensors do not appear in this mask i.e. not detected or not configured (see note in sensor depth input registers (30101).		
30009 – 30010		Mask of detected **moisture** sensors (Bit 0 is first moisture sensor, Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
30011 – 30012		Mask of detected **salinity** sensors (Bit 0 is first salinity sensor, Bit 1 is second salinity sensor, … Bit 16 is 17th sensor, etc)
30013 – 30014		Mask of detected **temperature** sensors (Bit 0 is first temperature sensor, Bit 2 is second temperature sensor, … Bit 16 is 17th sensor, etc)
30023 – 30024		**Humidity** of detected sensors (Bit 0 is first sensor, Bit 1 is second sensor, … Bit 16 is 17th sensor, etc) **Caition:** this humidity mask is not the consecutive address after the temperature mask
Sampled/Scanned Sensors Mask (moisture, salinity, temperature, humidity) At the start of reading, all scanned sensor masks are cleared, regardless of requested type. A bit is set after the cooked value is put in the corresponding input register. The bits in this mask are in the same order as the detected sensor mask. This mask should only be used to indicate the progress in scanning each sensor. It does not reflect failed sensors.		
30015 – 30016		Mask of sampled **moisture** sensors. This updates in real-time during a scan (Bit 0 is first moisture sensor, Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
30017 – 30018		Mask of sampled **salinity** sensors. This updates in real-time during a scan (Bit 0 is first salinity sensor, Bit 1 is second salinity sensor, … Bit 16 is 17th sensor, etc)
30019 – 30020		Mask of sampled **temperature** sensors. This updates in real-time during a scan (Bit 0 is first temperature sensor, Bit 1 is second temperature sensor, … Bit 16 is 17th sensor, etc)
30025 – 30026		**Humidity** Mask of sampled sensors. This updates in real-time during a scan (Bit 0 is first sensor, Bit 1 is second sensor, … Bit 16 is 17th sensor, etc) **Caution:** this humidity mask is not the consecutive address after the temperature mask

Absolute Address	Relative Address	Description
Configuration parameters. These parameters have been retained for compatibility with firmware versions before 1.4.1. They can no longer be used to algorithmically calculate humidity input register sensor mask addresses.		
30100	0x0063	Maximum number of sensors per each type supported (low byte) and the number of types allocated in the implementation (high byte). Each type has the same number of sensors. Note: type allocation does not necessarily imply hardware support at the time of issuing these specifications. Low byte MaxNumSens = 32 High byte NumTypes = 0 (for backward compatibility)
Sensor Depth Information These registers give the depth of each sensor (dimensionless values). Any register with a depth of zero is not by default configured and will not be in the mask of detected sensors. PConfig allows sensor depths up to 9995.0 but Modbus constrains this to 6553.5 (0xFFFF).		
30101 – 30132	0x0064	**Moisture** sensor depth information: Depth of first, second, third, etc moisture sensors. The value is multiplied by 10 to give accuracy to one fixed decimal point (e.g. “102” means “10.2”)
30133 – 30164		**Salinity** sensor depth information: Depth of first, second, third, etc salinity sensors. The value is multiplied by 10 to give accuracy to one fixed decimal point.
30165 – 30196		**Temperature** sensor depth information: Depth of first, second, third, etc temperature sensors. The value is multiplied by 10 to give accuracy to one fixed decimal point
30197 – 30228		**Humidity** sensor depth information: Depth of first, second, third, etc sensors. The value is multiplied by 10 to give accuracy to one fixed decimal point
Sampled Cooked Data (IEEE floating point 32-bit number) These registers are updated with cooked data as the reading progresses. The corresponding bit in the sampled sensor mask is then updated. The master device can read cooked data while the status register 30002=1 but only when the sensor's sampled/scanned bit mask is 1. After a read of selected sensors, sensors not selected (scanned) get a cooked value of 0.0. Valid cooked moisture values will always be in the range +0.0 to +101.0. Data that results in values in the range -0.1 to 0.0 will be returned as +0.0. Any data values outside of this range (caused by faulty sensors, incorrect probe installation or inappropriate calibration equation coefficients) will be returned as IEEE Not-a-Number (7FC00000). A failed sensor will also return a value of Not-a-Number.		
30257 – 30320	0x0100	In pairs, cooked **moisture** sensor readings of the first, second, third, etc moisture sensors as 32-bit IEEE floating point numbers (low word in lower register address). Updated dynamically as reading progresses.
i30321 - 30384		In pairs, cooked **salinity** sensor readings of the first, second, third, etc sensors as 32-bit IEEE floating point numbers (low word in lower register address). Updated dynamically as reading progresses.
30385 - 30448		In pairs, cooked **temperature** sensor readings of the first, second, third, etc sensors as 32-bit IEEE floating point numbers (low word in lower register address). Updated dynamically as reading progresses.

Absolute Address	Relative Address	Description
30449 - 30480		In pairs, cooked **Humidity** sensor readings of the first, second, third, etc sensors as 32-bit IEEE floating point numbers (low word in lower register address). Updated dynamically as reading progresses.

Holding Registers

Note: In writing to multiple Holding Registers, the higher address registers are in fact written to first; this permits a preset multiple registers command to both set the selection mask and initiate a reading (40001=1).

Absolute Address	Relative Address	Description
40001	0x0000	Command Register; write to this to start a sensor reading 0 = No action 1 = Read sensors specified in mask (40002 through 40009) 2 = Read all (detected) moisture sensors 3 = Read all (detected) salinity sensors 4 = Read all (detected) temperature sensors 5 = Read all (detected) humidity sensors Writing other values, or writing while the value is non-zero will cause an exception response- Illegal data value. This register should not be updated while a reading is in progress (30002=1)
Selection mask for the sensors to be sampled Only sensors with their corresponding bit set will be scanned, other sensors will get a cooked value of 0.0. The bits in this mask are in the same order as the detected sensor mask.		
40002 – 40003	0x0001	**Moisture** sensor selection mask register (use in conjunction with 40001 = 1) (Bit 0 is first moisture sensor Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
40004 – 40005		**Salinity** sensor selection mask register (use in conjunction with 40001 = 1) (Bit 0 is first salinity sensor Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
40006 – 40007		**Temperature** sensor selection mask register (use in conjunction with 40001 = 1) (Bit 0 is first temperature sensor Bit 1 is second moisture sensor, … Bit 16 is 17th sensor, etc)
40008 – 40009		**Humidity** sensor selection mask register (use in conjunction with 40001 = 1) (Bit 0 is first sensor Bit 1 is second sensor, … Bit 16 is 17th sensor, etc)

Register Retention

If the probe is powered down, contents of all Modbus registers are cleared. At power on, the probe will initialize detected sensors mask (registers 30009 through 30014 and 30023-30024), maximum number of sensors/types (register 30100) and sensor depths (registers 30101 through 30228) from its configuration data when power is restored.

Data Types

As per Modbus Protocol specification, all registers (16 bit) are represented as Big Endian format.

There is no specified representation for 32 bit words in either integer or floating point.

This implementation uses a mixed big/little endian format that appears to be the most commonly implemented method on Intel platforms.

The format of the mixed big/little endian is as follows:

Absolute Address 1 (Relative 0)		Absolute address 2 (Relative 1)	
32 Bit Data			
Low word		High word	
Bits 15 to 8	Bits 7 to 0	Bits 31 to 24	Bits 23 to 16
16 Bit Data			
Bits 15 to 8	Bits 7 to 0	Bits 15 to 8	Bits 7 to 0

Figure 8 Format of mixed big/little endian

The low word is in the lower register address.

Big endian implementations will need to swap Reg1 and Reg2 and concatenate them to obtain a value that is equivalent to the native form.

Little endian implementations should not need to modify anything as most Modbus drivers implemented on Little endian systems internally swap the bytes within the Modbus register before passing up to the application.

Data Reading

Note: Probe interface must be configured correctly to obtain valid readings from the Modbus port. See section Setting up the probe interface for more information.

This example shows the process to read moisture sensors.

1. Ensure there is no measurement in progress (input register 30002 <> 1).
2. To start a reading of all configured sensors, preset single holding register 40001 to the value 2, or
   To start a reading of selected sensors, preset multiple holding registers to 40001 value 1 and 40002-40003 with desired moisture sensors selection mask, and 40004-40009 masks to zero.
   The input registers are updated
   30001 is the last command executed (i.e. it mirrors the last value written to 40001),
   30002 is the current status (dynamically updated),
   30003 through 30008 and 30021-30022 is the selection mask used (taken from 40002 through 40009).
3. Reading progress can be monitored in register 30002; a value of 1 means the measurement is in progress; 2 means measurement completed, while 3 means sensor failure occurred during measurement. Failed sensors have a cooked value of Not-a-Number.
4. Register 30009- 30014 and 30023-30024 is the selection mask of detected sensors.
5. Register 30015- 30020 and 30025-30026 is a selection mask of registers processed during a reading; it is updated as the reading progresses.
6. Registers 30101 through 30228 contain the depths of each sensor. The value is an integer scaled up by 10 to give accuracy to one decimal point. There are no units assigned to this value, it is dimensionless.
7. Registers 30257 through 30320 contain cooked moisture data values; Consecutive pairs of registers are an IEEE 32-bit floating point number (the lower register address contains the low word). These are all set to zero on a measurement request, and updated as the request progresses. Invalid conversions (e.g. configured sensor failed) are stored as IEEE “Not a Number.”

Salinity Sensor considerations

When the interface samples salinity sensors it also samples the corresponding moisture sensors. Consequently, after sampling salinity sensors, cooked data is available for both moisture (registers 30257- 30320) and salinity (registers 30321-30384). Hence a separate command to read moisture data is not required.

Temperature and Humidity Sensor Reading

All configured temperature sensors can be read by sending preset single holding register 40001 to the value 4. When the reading has completed (30002 <>1), the temperature values are available as IEEE floating point values in input registers 30385–30448.

All configured humidity sensors can be read by sending preset single holding register 40001 to the value 5. When the reading has completed (30002 <>1), the humidity values are available as IEEE floating point values in input registers 30449-30480.

Alternatively, all moisture, salinity, temperature and humidity sensors can be read with one preset multiple holding registers command. Set 40001 to value 1, 40002-40009 to 0xFFFF,0, 0xFFFF,0, 0xFFFF,0, 0xFFFF,0. Although the masks are set for all 16 registers, only detected sensors are returned using detected sensor masks 30009-30014 and 30023-30024. The values for all detected sensors are available as IEEE floating point values in input registers 30257-30480. IEEE Floating point value 0.0 is returned for non-existent sensors.

Maximum Message Length

The maximum message length of a Modbus message is 255 bytes. Within the current implementation the maximum message lengths are:

- RTU mode
  =32 sensors × 2-bytes + address 1-byte + function 1-byte + CRC 2-bytes

= 68 bytes

- ASCII mode
  = 32 sensors × 4-bytes + address 2-byte + function 2-byte + LRC 2-bytes + colon-prefix 1-byte + <CR><LF> 2-bytes
  = 137 bytes

Communication Parameters

The Modbus output port communication parameters are set using the Probe Configuration Utility, on the Modbus page. The available parameters are:

Baud rate	1200, 2400, 4800, 9600 (*default*), 19200 bits per second
Data bits	7, 8
Parity	None (*default*), Even, Odd
Stop bits	1, 2 (*default*)

Note: The RS232 probe interfaces use hardware-handshaking. The probe interface will raise RTS before sending a response message, and waits for CTS before transmitting the response. The interface acts as a half-duplex DTE device.

Note: If the probe interface is directly connected to a computer serial port, the following information should be noted.

1. Using an RS232 connection, both CTS and RTS lines must both be open circuit (both attempt to raise RTS)
2. Using an RS485 connection, an RS232 to RS485 converter should be configured as a DCE, 2-wire with no RTS.

Technical Specifications

EnviroSCAN RS232 Series II Technical Specifications

PCB Revision: REV 2.3

Identification Label: XPI-SC-232

RS232 Interface connector type: Brand: Phoenix Contact

MC 1,5/8-ST-3,5 (Plug)

MC 1,5/8-G-3,5 (Socket)

RS232 Interface pin configuration:

1. +V*in*
2. Reserved
3. Reserved
4. Ground
5. TX – RS232 Data
6. RX– RS232 Data
7. Request to send (RTS)
8. Clear to Send (CTS)

Note: Where RTS and CTS lines are not connected to the Modbus master device, it is recommended that these two pins be linked together.

Voltage Supply (RS232 +Vin**):** 4 - 15 Volts (12 Volts DC @ >200mA recommended)

Fuse specification: F201 Vin Littelfuse 0154-500 (500mA fast blow)

F202 Telemetry (unused in Modbus)

Jumper pins: JP201 Telemetry switch (unused in Modbus)

RS232 Interface baud rate: 1200, 2400, 9600 (*default*), 19200 and 38400 bits per second (user configurable)

TTL Interface connector type: Brand: JST

B 6B-PH-K (Socket)

PHR- 6 (Plug), SPH-002T-P0.5S (Crimp connectors)

TTL Interface pin configuration:

1. +V*cc*
2. Transmit data (T*x*)
3. Receive data (R*x*)
4. Reserved
5. Reserved
6. Ground

Voltage Supply (TTL +Vcc): 5 Volts, supplied by the EnviroSCAN probe interface

TTL Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

Total current consumption: 400µA @ standby

105mA @ sampling (Moisture) @12V DC

130mA @ Sampling (TriSCAN) @12V DC

Time to sample 1 sensor: 45 milliseconds maximum (Moisture only)

90 milliseconds maximum (TriSCAN)

Maximum sensors supported: 16 Moisture Sensors

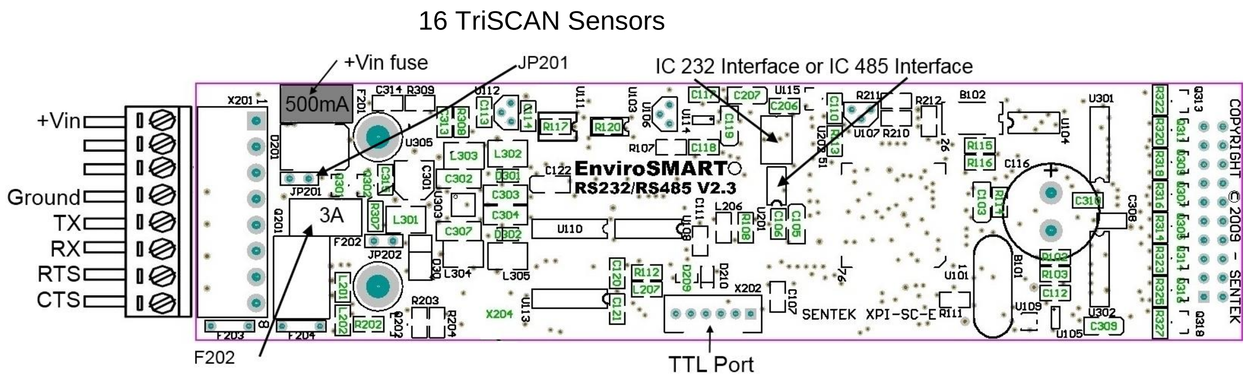

Figure 9 **EnviroSCAN** RS232 Modbus probe interface board layout

EnviroSCAN RS485 Series II Technical Specifications

PCB Revision: REV 2.3

Identification Label: XPI-SC-E-RS485

RS485 Interface connector type: Brand: Phoenix Contact
MC 1,5/8-ST-3,5 (Socket)
MC 1,5/8-G-3,5 (Plug)

RS485 Interface pin configuration:

1. +V*in*
2. Reserved
3. Reserved
4. Ground
5. A – RS485 Data
6. B – RS485 Data
7. Screen
8. *Reserved*

Voltage Supply (RS485 +Vin**):** 4 – 15 Volts (12 Volts DC @ >200mA recommended)

Fuse specification: F201 Vin Littelfuse 0154-500 (500mA fast blow)
F202 Telemetry (unused in Modbus)

Jumper pins: JP201 Telemetry switch (unused in Modbus)
JP202 RS485 Teminator

RS485 Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

TTL Interface connector type: Brand: JST
B 6B-PH-K (Socket)
PHR- 6 (Plug), SPH-002T-P0.5S (Crimp connectors)

TTL Interface pin configuration:

1. +V*cc*
2. Transmit data (T*x*)
3. Receive data (R*x*)
4. *Reserved*
5. *Reserved*
6. Ground

Voltage Supply (TTL +Vcc): 5 Volts, supplied by the EnviroSCAN probe interface

TTL Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

Total current consumption: 400µA @ standby @ 12V DC

105mA @ sampling (Moisture) @ 12V DC

130mA @ Sampling (TriSCAN) @ 12V DC

Time to sample 1 sensor: 45 milliseconds maximum (Moisture only)

90 milliseconds maximum (TriSCAN)

Maximum sensors supported: 16 Moisture Sensors

16 TriSCAN Sensors

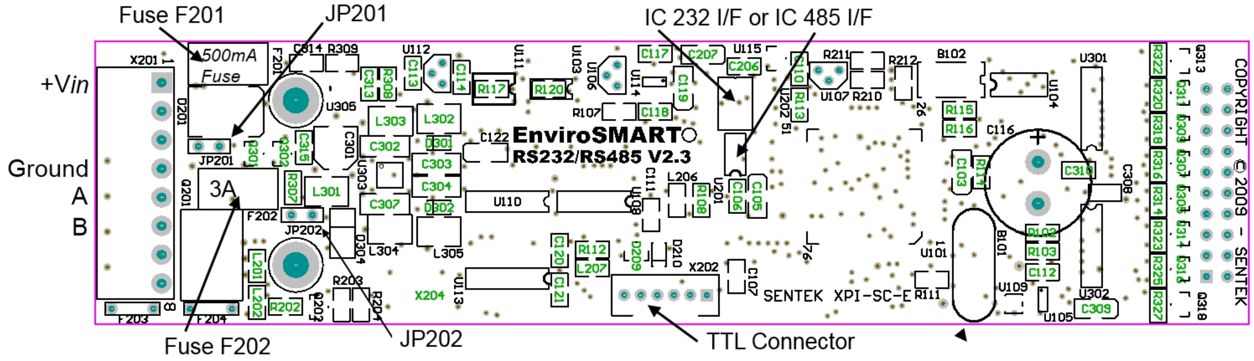

Figure 10 **EnviroSCAN** RS485 Modbus probe interface board layout

EasyAG RS232 Series II Technical Specifications

PCB Revision: PCB 0681 V2.4

Identification Label: XPI-SC-I-RS232

RS232 Interface connector type: Brand: Phoenix Contact

MPT0.5/8-2.54

RS232 Interface pin configuration:

1. +V*in*
2. Reserved
3. Reserved
4. Ground
5. TX – RS232 Data
6. RX– RS232 Data
7. Request to send (RTS)
8. Clear to Send (CTS)

Note: Where RTS and CTS lines are not connected to the Modbus master device, it is recommended that these two pins be linked together.

Voltage Supply (RS232 +Vin**):** 4 – 15 Volts (12 Volts DC @ >200mA recommended)

Fuse specification: F201 Vin Littelfuse 0154-500 (500mA fast blow)

F202 Telemetry (unused in Modbus)

Jumper pins: JP201 Telemetry switch (unused in Modbus)

RS232 Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

TTL Interface connector type: Brand: JST

S6B-PH-SM3-TB

PHR- 6 (Plug), SPH-002T-P0.5S (Crimp connectors)

TTL Interface pin configuration:

1. +V*cc*
2. Transmit data (T*x*)
3. Receive data (R*x*)
4. Reserved
5. Reserved
6. Ground

Voltage Supply (TTL +Vcc): 5 Volts, supplied by the EasyAG probe interface

TTL Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

Total current consumption: 400µA @ standby

102mA @ sampling (Moisture)

126mA @ Sampling (TriSCAN)

Time to sample 1 sensor: 45 milliseconds maximum (Moisture only)

90 milliseconds maximum (TriSCAN)

Maximum sensors supported: 5 Moisture Sensors

5 TriSCAN Sensors

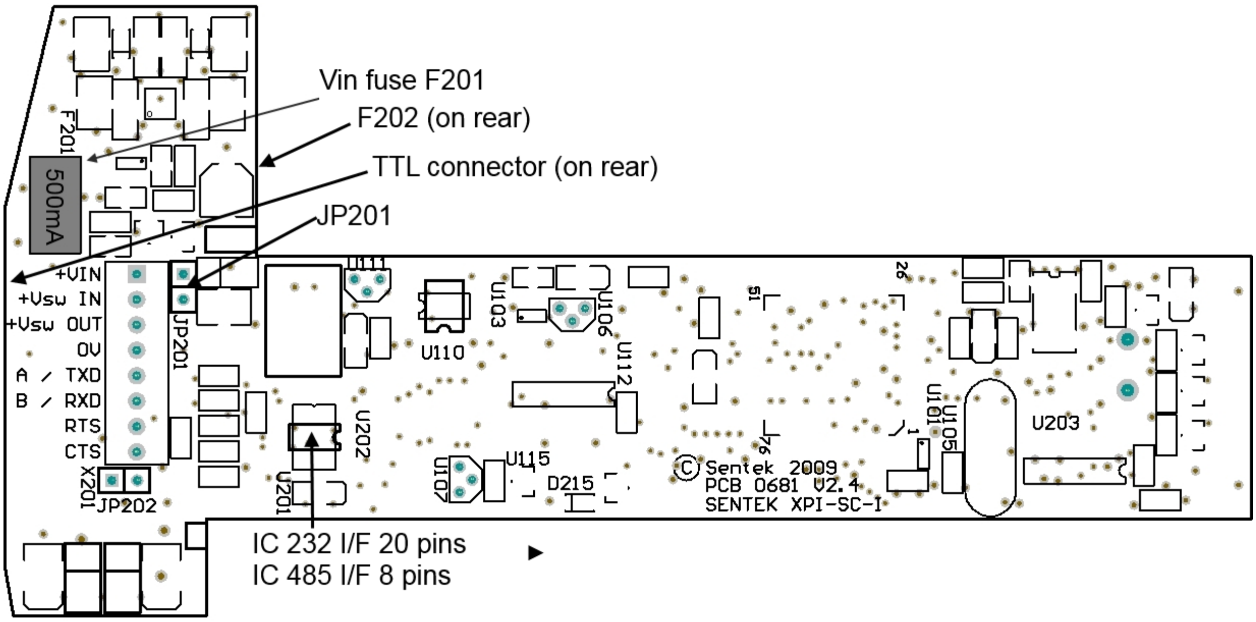

Figure 11 **EasyAG** RS232 Modbus probe interface board layout

EasyAG RS485 Series II Technical Specifications

PCB Revision: PCB 0681 REV 2.4

Identification Label: XPI-SC-I-RS485

RS485 Interface connector type: Brand: Phoenix Contact

MPT0.5/8-2.54

RS485 Interface pin configuration:

1. +V*in*
2. Reserved
3. Reserved
4. Ground
5. A – RS485 Data

6. B – RS485 Data
7. Screen
8. *Reserved*

Voltage Supply (RS485 +Vin): 4 – 15 Volts (12 Volts DC @ >200mA recommended)

Fuse specification: F201 Vin Littelfuse 0154-500 (500mA fast blow)

Jumper pins: JP202 RS485 Teminator

RS485 Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second (user configurable)

TTL Interface connector type: Brand: JST

B 6B-PH-K (Socket)

PHR- 6 (Plug), SPH-002T-P0.5S (Crimp connectors)

TTL Interface pin configuration:

1. +V*cc*
2. Transmit data (T*x*)
3. Receive data (R*x*)
4. *Reserved*
5. *Reserved*
6. Ground

Voltage Supply (TTL +Vcc): 5 Volts, supplied by the **EasyAG** probe interface

TTL Interface baud rate: 1200, 2400, 9600 (*default*), 19200 and 38400 bits per second (user configurable)

Total current consumption: 400µA @ standby

102mA @ sampling (Moisture)

130mA @ Sampling (TriSCAN)

Time to sample 1 sensor: 50 milliseconds maximum (Moisture only)

50 milliseconds maximum (TriSCAN)

Maximum sensors supported: 5 Moisture Sensors

5 TriSCAN Sensors

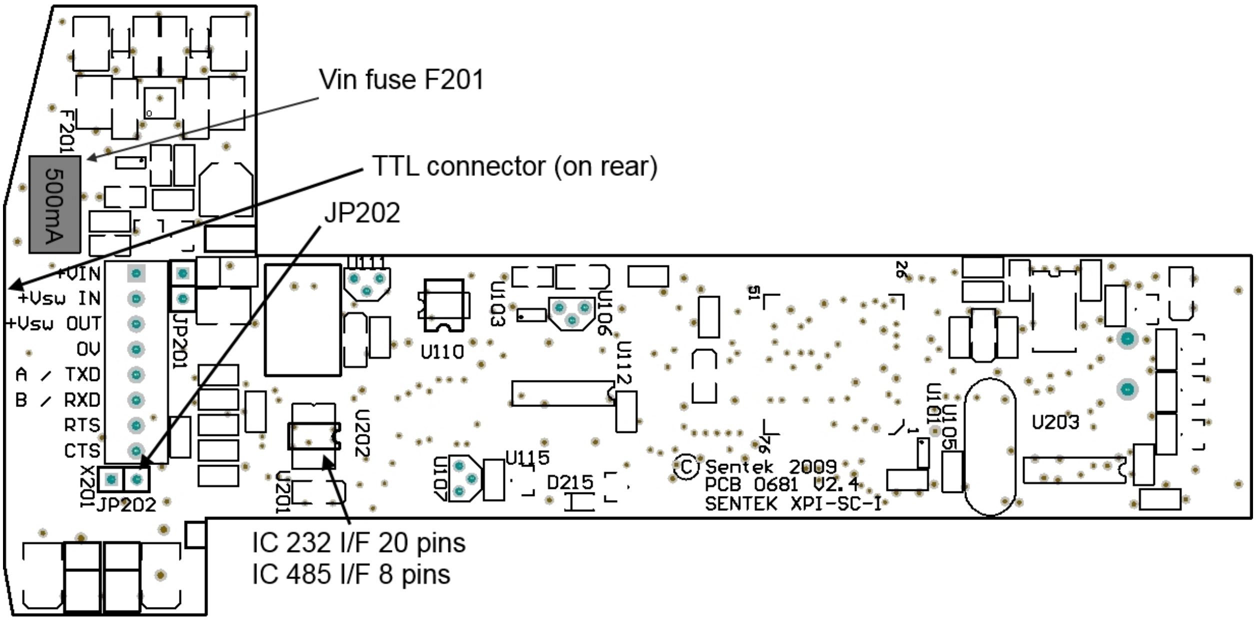

Figure 12 **EasyAG** RS485 Modbus probe interface board layout

Drill & Drop Technical Specification

The Drill & Drop interface box encapsulates an EnviroSCAN RS232 or RS485 Interface.

Caution:
The RS485 interface does not have a jumper on JP202 terminator. If line termination is required, a 120 ohm resistor should be connected between the A and B lines, close to the Interface box.

Identification Label: Drill & Drop Probe
Moisture, salinity (optional), temperature
Plus (232) Modbus or Multi (485) Modbus

Current consumption (RS232/RS485): 400µA standby @ 12 V DC

9mA Active @ 12 V DC

25mA @ 12 V DC** Average current over sensor sampling period.

800uA standby @ 6 V DC

16mA Active @ 6 V DC

45mA @ 6 V DC ** Average current over sensor sampling period.

Current is measure at the interface, production version 2.4 manufactured in 2013.

Time to sample 12 sensors: 1.8 seconds for Moisture and Temperature

(approx. 150ms per sensor **)

2.2 seconds for Moisture, TriSCAN and Temperature

(approx. 180ms per sensor **)

Time to sample 6 sensors: 1.3 seconds for Moisture and Temperature

(approx. 215ms per sensor **)

1.1 seconds for Moisture, TriSCAN and Temperature

(approx. 180ms per sensor **)

**** Note:** Sensor measurement time is approximate and an average of the total time to measure all sensor types at a single depth.

Sensors are measured starting from the bottom sensor (6 or 12)

Moisture Sensor Resolution: 1:10000

Moisture Sensor Precision: +/- 0.03% vol.

TriSCAN Sensor Resolution: 1:6000

Temperature Sensor Accuracy: +/- 2 Deg. C @ 25 Deg C.

Temperature Sensor Resolution: 0.3 Deg C.

Voltage Supply (TTL +Vcc): 5 Volts, supplied by the interface box

TTL Interface baud rate: 1200, 2400, 9600 (default), 19200 and 38400 bits per second

EnviroSCAN and EasyAG RS232 and RS485 Circuit Information

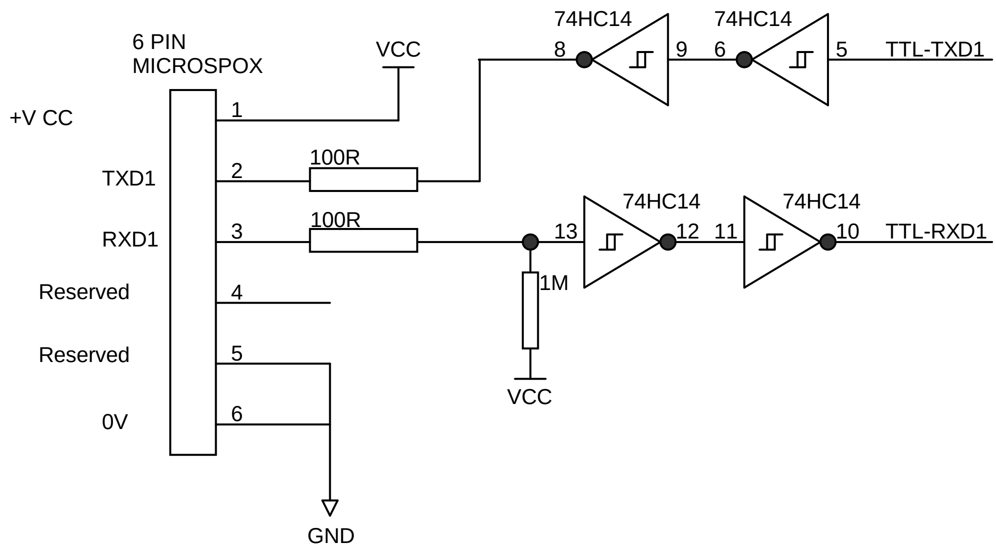

Figure 13: TTL interface circuit diagram

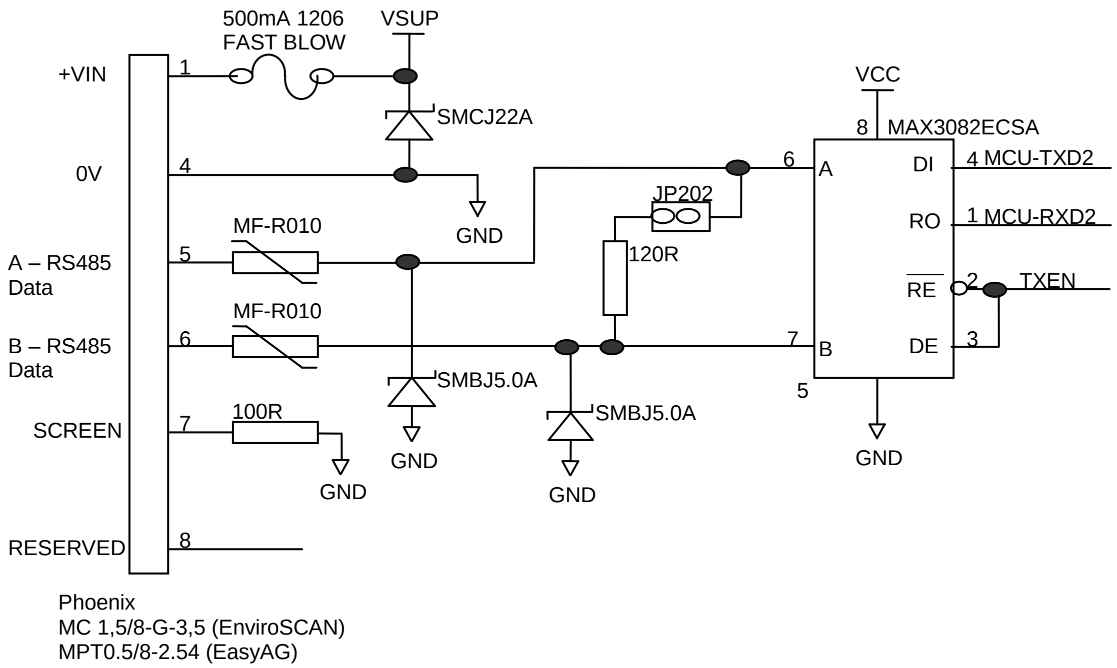

Figure 14: RS485 interface circuit diagram

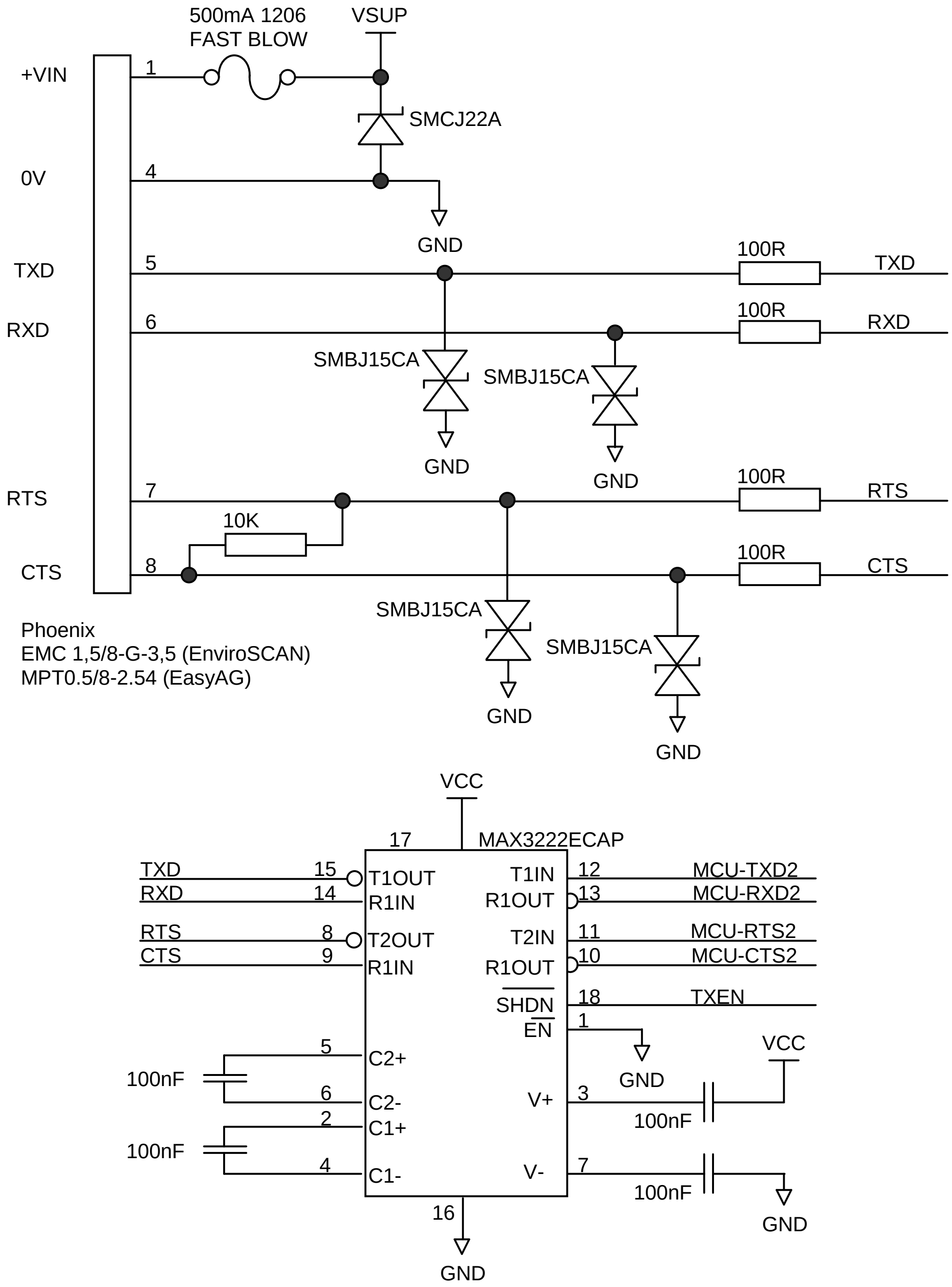

Figure 15: RS232 interface circuit diagram

Appendix A – Sentek Modbus Master Device Guidelines

Objective

The objective of this appendix is to give guidelines to developers/vendors of the Modbus master device for Sentek Modbus slave devices, to allow them to develop an implementation of the master device code which would remain compatible with future versions of Sentek Modbus slave devices including new types of such devices and Sentek Windows Software.

Scope

This appendix does not cover full code or algorithms, which could be deemed as a provision of routines or subroutines. It presents only a high-level description to give an idea and understanding of how the Modbus registers exposed by the Sentek devices should be used properly for maintaining compatibility with future Sentek slave devices.

AutoSDB is mentioned as to how the master should determine which data from the slave should be put into the DB (please refer to “AutoSDB Programmers’ Manual” for full information on tables and fields available through AutoSDB).

Background

Sentek devices by their nature are highly configurable based on the customer needs. This high level of variation in the configurations, as well as continuous development of new types and sizes/capacities of the devices requires that the master understands the configuration of the device that is attached to it. On top of that, assuming that the logged and retrieved data is then to be transferred into Sentek IrriMAX software, the master needs to know where in the database (data columns) the retrieved data belongs.

Falling short of this consistency could result in the Modbus master becoming incompatible with other than tested variations of the product not to mention future products, which could have extended functionality.

Guidelines

Variations/changes that the Modbus master device should be able to handle without any need to change its software are:

- Varying number of sensors on the probe
- Varying sensor addresses for the same sensor depth level
- Varying depth settings for the same sensor address
- Increased maximum number of sensors supported by probe – hence Modbus register addresses
- New sensor types introduced
- Consider the RS485 communication line turn-around time (Modbus parameter in the Sentek Probe Configuration Utility)

The master does not have to understand the future types, however the introduction and support of those types in the slave devices need not break the compatibility with the master software.

The Master therefore should follow rules in how to query the configuration, how to trigger the measurement, how to retrieve the data and then on the computer side (under Windows) how the data is to be properly put into the IrriMAX database.

Rule #1 (“Little Endian” vs. “Big Endian”)

Every multi-word (multi-register) data is stored in a “little endian” style, that is, lower word (2 bytes) is stored at the lower address and, higher words are stored at higher addresses. This also applies to IEEE float numbers.

Note that the register (word) itself is communicated between the Sentek Modbus slave devices and the Modbus master devices in a “big endian” style (as per standard Modbus specification), that is, higher byte comes first, followed by lower byte.

Rule #2 (Master initialisation)

As of version 1.4.1 of the firmware the input register and holding registers are at fixed locations as specified in the tables in the ***Error! Reference source not found.*** section.

Sentek Firmware version 1.4.1 added Humidity sensors. To preserve backward compatibility, the humidity register masks are stored after existing moisture, salinity and temperature masks.

These locations may be changed the future devices.

Rule #3 (Bitmask register sizes)

Bit masks should be considered as a string of 32 bits.

Rule #4 (Address calculations)

Caution: This rule only applies to firmware before version 1.4.1, which does not support temperature and humidity sensors.

Calculate the beginning of the Modbus address space for each sensor type for various types of data instead of hard coding.

There are various data tables available through the Modbus address space. Each of these tables cover all allocated types of sensors, hence the size of the table is dependent on the number of “sensor types” allocated and the maximum number of sensors allocated per type.

$$A_{TypeStart} = (T - 1) \times A_{MoistureStart}$$

where

$A_{TypeStart}$ is the first register address of a specific “info” table for the specific sensor type

T is the sensor type code [moisture=1, salinity=2, etc]

$A_{MoistureStart}$ is the first register address of a specific “info” table for the moisture type (see following)

Note: The “maximum number of sensors” per type or the “number of types” allocated in the Modbus address space only defines register location. It does not imply hardware support.

Rule #5 (Depth information)

Retrieve the “Depth Information” from the “Depth” table (input registers 30101-30228) for every sensor detected.

The depth information should be used as a ”key” for matching the retrieved data with the database tables (i.e. Sentek IrriMAX software) to ensure that the data integrity is maintained automatically even if sensor addressing is changed.

For example, the 3rd party software retrieving the moisture data from the probe would thus know that for instance the first sensor has a depth set up to 10cm, hence when putting the data into the IrriMAX database, the software is able to find the right table and column (using AutoSDB functions), which hold the data for the depth level of 10cm, to have the data written into the right place.

Note: The 3rd party software linking to Sentek IrriMAX software (using AutoSDB interface) can query the appropriate database table to determine what column holds the data for which depth level. The depth level information is one of the fields exposed through the AutoSDB interface.

Appendix B – Soil Moisture Management

What soil volume does the probe interface measure at a single sensor?

At a single depth level, a sensor on the probe records volumetric water content from a soil volume outside the access tube, which has a sphere of influence of:

- 10cm vertical height
- 5-10cm radial distance from the outer wall of the access tube

What are the water units?

If a calibrated sensor reads one(1) millimeter, there is one(1) millimeter of volumetric water content in a soil volume 10cm deep.

Q. What does 1mm volumetric water content / 10cm soil depth mean?

A. You require one(1) liter of water to cover one(1) square meter (m^2) to a soil depth of one(1) millimeter.

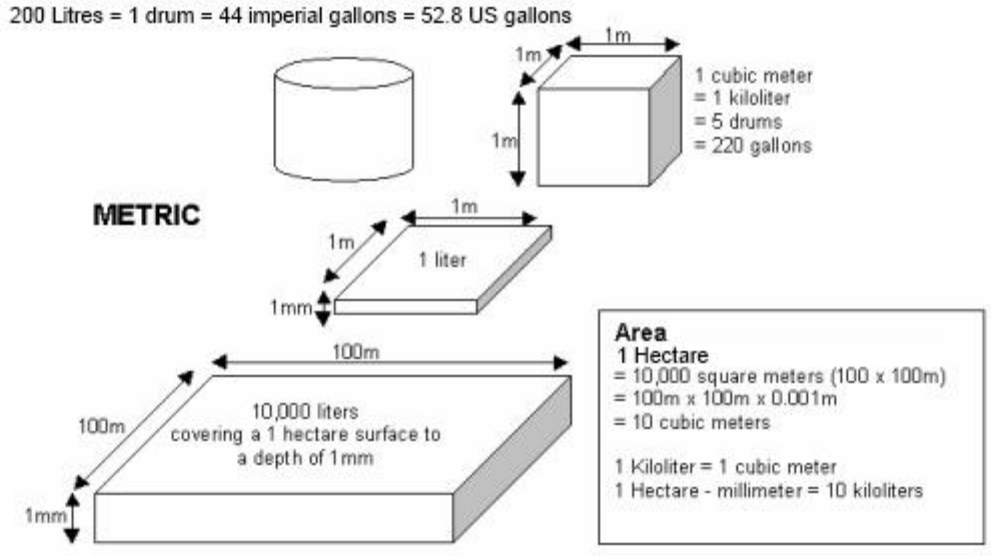

Figure 13 Measurements using metric units

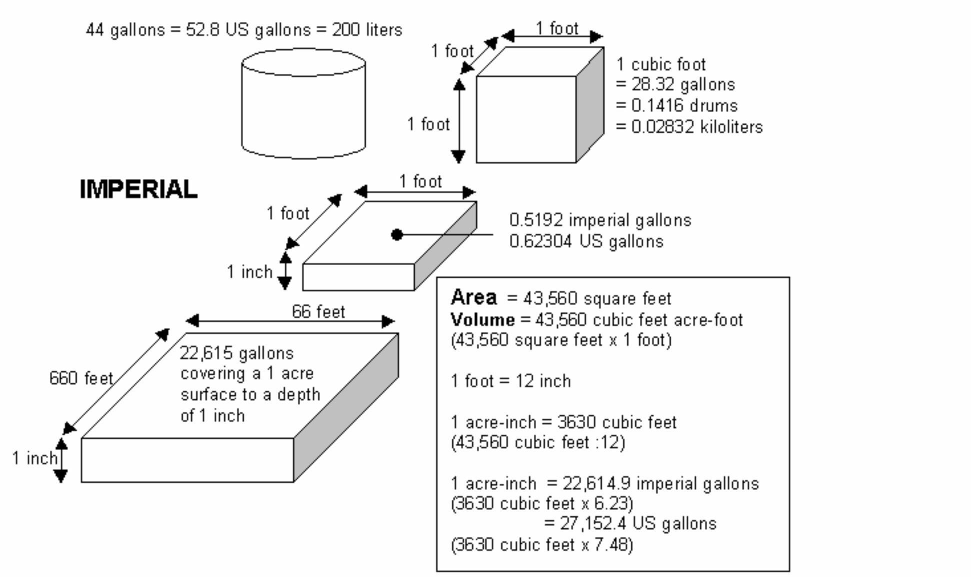

Figure 14 Measurements using imperial units

What part of the soil profile do multiple sensors on the probe measure?

Probes in almost all cases have more than one sensor to monitor the depth of irrigation and the depth of the root zone. The first sensor is located at a soil depth of 10cm (if the datum plate of the top cap sits on ground level) measuring effectively the soil profile slice of 5-15cm depth. The next sensor is located at 20 cm measuring effectively 15 –25cm soil depths. With further sensors at 10cm intervals on the probe rod, the measurement depth would be respectively (25-35cm, 35-45cm and so on).

If you raise the datum plate of the top-cap 5cm above the ground surface, placing the center of the first sensor effectively at 5cm soil depth, the sphere of influence of the sensor will measure a soil slice from 0-10cm. For the other sensors at 10cm depth intervals on the probe rod, the measurement depth would be respectively (20-30cm, 30-40cm and so on).

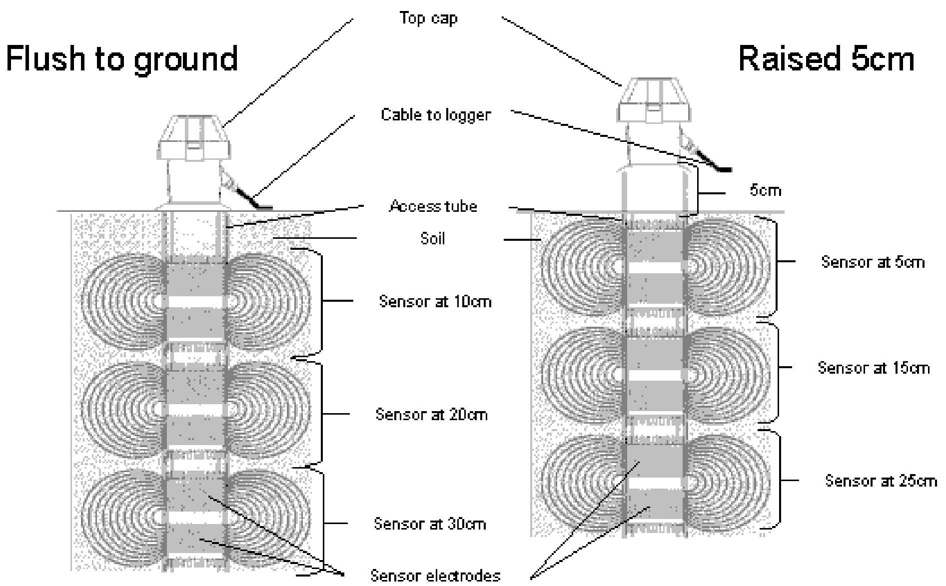

Figure 15 Measurements of multiple sensors on the EnviroSCAN probe

Appendix C – Salinity Management

Please refer to the "TriSCAN™ Agronomic User Manual" for detailed information on measuring and interpreting salinity. The following information has been extracted from that manual.

Sensor output and measurement units

The TriSCAN sensor provides two outputs.

The first output is a signal of dimensionless frequency (raw count), that is converted via a normalization equation and then a default or user-defined calibration equation into volumetric soil water content. The measurement unit is thus volumetric water content (Vol %) or millimetres of water per 100 mm of soil depth

The second output is also a dimensionless frequency (raw count) that, in conjunction with the first output signal, is proportional to changes in soil water content and salinity. A proprietary data model processes the changes of both output signals simultaneously to reflect the changes that are due to soil salinity changes only. The output of the data model is a nominal Volumetric Ion Content (VIC). Measurement units of VIC can be quantitatively related (calibrated) to the soil EC through site specific physical soil sampling and analysis. Similar to the soil water data, the sensor output of VIC can be presented as dynamic trend changes over a chosen time scale.

Measurement Range

The effective measurement range of TriSCAN is between 0 and 17 dS/m.

Resolution and Accuracy

The resolution and accuracy of the sensor can be considered in terms of the two different outputs: Volumetric Water Content: and Salinity:

To date, statements on the resolution and accuracy of the salinity output can only be made with regards to the particular type of sand that has been used to develop the TriSCAN data processing models. These specifications do not necessarily reflect the resolution and accuracy of the sensor on any other soil type.

The accuracy and precision of the sensor in the tested sand were as follows:

- In saturated soil conditions at low EC 55µS/cm:
  Repeatable change of VIC's related to a resolution of 1 µS/cm (Accuracy ±1.8%)
- In saturated soil conditions at medium EC up to 5600 µS/cm:
  Repeatable change of VIC's related to a resolution of 25 µS/cm (Accuracy ± 0.4%)

Temperature Effects

The temperature effects on TriSCAN data output are currently unknown. It is however, known that the electrical conductivity of solutions and of soils increases by approximately 2.25% per degree Celsius. To simplify the interpretation of salinity data, it is customary in the industry either to take the measurements at a standard reference temperature or to determine the temperature at which the measurement is made, and then, by means of a correction table or model, to convert the measurement to the standard-reference temperature.

The TriSCAN model currently does not include such a temperature correction model.

Why TriSCAN does not measure individual plant nutrients (ions)?

Soil salts are chemical compounds that are dissolved in soil solutions. Salts are comprised of anions such as carbonates, chlorides, sulfates and nitrates, and cations such as potassium, magnesium, calcium and sodium. In ambient conditions, these compounds are present in proportions that create a balanced ionic or charged solution.

Under natural soil conditions TriSCAN™ is unable to discern individual salt compounds.

As equivalent concentrations of some salts show a varying degree of conductivity, the distinction between different single salt solutions can only be made by measuring the conductivity of an equivalent salt concentration of a single salt source in solution comparatively. TriSCAN™ would detect this difference in conductivity, but it could not indicate the identity of the single salt compounds.

In what soil types does TriSCAN work?

The effective measurement range of TriSCAN is between 0 and 17 dSm-1 in sand, loamy sand and sandy loam textures (Australian Soil and Land Survey Field Handbook). Use of TriSCAN at salinity levels and soil textures outside this range is currently unsupported by Sentek.

Data logging requirements for TriSCAN

Consideration should be made to the power and timing requirements when using TriSCAN sensors. In particular:

- Taking a salinity reading requires 100 milliseconds per sensor
- Salinity sensors use slightly higher current draw than moisture sensors.

See the Technical Specifications section for more detail.

