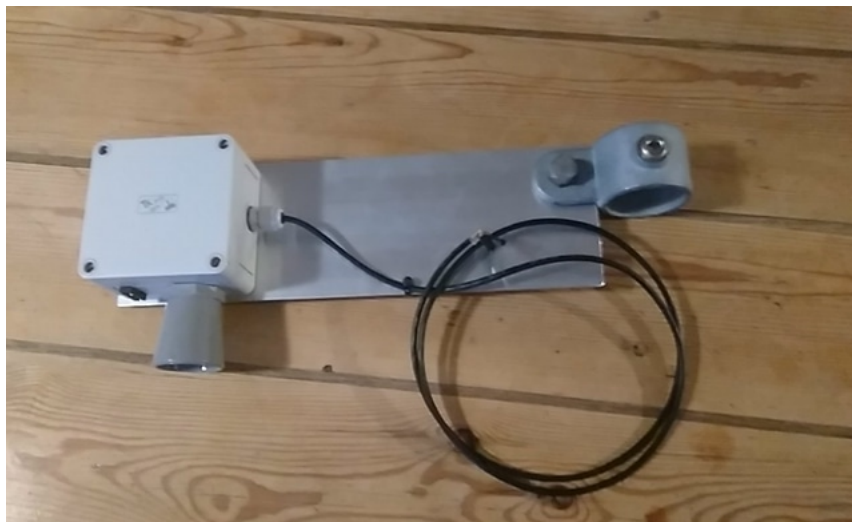## Ystumtec Ltd.

CH1 crop height sensor user guide (V1.2)

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1 Overview

The sensor is designed to be mounted above growing crops in the field in order to measure their height. The sensor box is supplied with a mounting bracket to allow attachement to a scaffold clamp such as a Key Clamp 173M as shown in the picture above. This allows the sensor to be mounted on a standard scaffold tube that is driven into the ground. We recommend a depth of 500mm for a sensor mounting height of 1.5m, although this may vary depending on the soil type and wind exposure of

Colour	Function	Nominal	Limits
Red	Power in	5V 500mA	4.5V to 5.5V 600mA
Blue	Ground	0V -500mA	0V -600mA
Green	RX: data in	0 or 3.3V <1mA	-0.1V to 3.4V +/-2mA
Yellow	TX: data out	0 or 3.3V <1mA	0V to 3.4V +/-2mA
Shield	Ground	0V -1mA	0V -100mA

Table 1: Cable colours and functions

the site. The sensor is weather-proof and does not require protection from rain. Depending on local conditions you may need to protect the cable from attack by birds, rodents and other wildlife.

This unit requires a microcontroller, computer or other control system to be connected in order to capture and store the data collected.

1.1   Physical Considerations

The enclosure must be mounted with the horn of the ultrasonic sensor pointing downward towards the crop to be measured and the cable must be routed to be clear of both the ultrasound horn and the infra-red sensor lenses. The cable is supplied cable-tied to the mounting bracket in order to keep it clear of the sensors: if you remove the cable-tie be sure to keep the cable clear of the sensors in the final mounting position.

1.2   Electrical Considerations

The sensor requires a regulated 5V power supply that is capable of supplying peak currents up to 500mA for up to 100ms. The asynchronous serial communication port uses 3.3V signal levels in a"standard logic" configuration (1 is HIGH, 0 is LOW). All communications are carried out using ASCII encoding of the protocol descibed below. The sensor will tolerate an absolute maximum of 5.5V input and will continue to operate down to around 4.5V although performance will be impaired as the ultrasonic sensor operates at reduced power below 5V.

1.3   Sensing

Crop height is measured to the nearest centimetre by both the ultrasonic and infra-red sensors. Both sensors can return higher resolution than this, but the
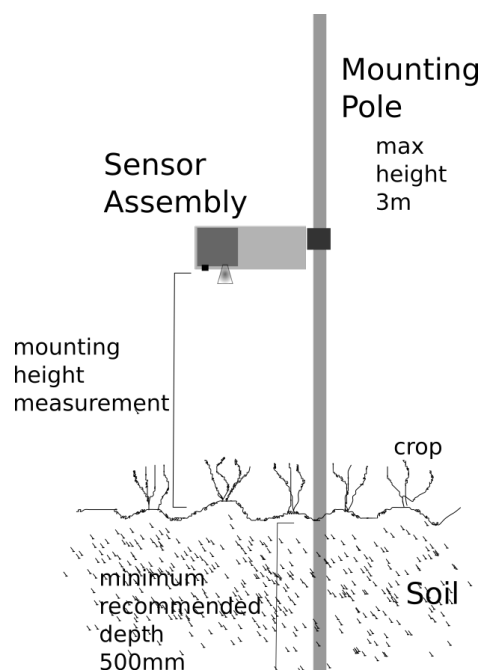
repeatability of these kinds of measurements in the field is not sufficiently good to warrant the production of data at better than 1cm resolution. The mounting height should be measured and rounded **up** to the nearest 10cm. The unit will use this as a datum from which to measure, but in order to interpret this data appropriately an initial reading should be taken from the infra-red sensor for use as a calibration offset for all future readings. For example, if an initial reading of 3cm is returned before the crop has emerged then this should be subtracted from all future readings of crop height. If an initial value of zero is returned then either the unit is mounted too high and it should be adjusted down the pole, or the height configuration parameter should be increased by 10cm (see protocol below). The default height value is set at 100cm. For use on cereal crops where monitoring of early growth stages is required the sensor should be mounted lower than this (we recommend 60cm) in order to maximize the likelihood of detection of fine shoots and leaves. It is also recommended to align the sensor directly over a crop row: if the crop is not within the view of the sensors then it will not be detected!

2   Data

The infra-red sensor makes a single measurement that detects the tallest obstacle within its field of view. This is returned as a single value in centimetres and is likely to vary considerably as the crop moves due to the action of the wind etc. Multiple measurements are recommended in order to generate repeatable data (an averaging function is offered by configuring the IR repetitions value: see protocol   below).

The sonar sensor is potentially a much richer source of information, but is less effective at detecting fine leaves and shoots such as the early stages of cereal crop growth. The sonar data is returned at configurable resolution (default 1cm) in the form of signal intensity returned at different crop heights. For example if the mounting height is set to 60cm and the resolution is left at the default value of 1cm then a string of 60 values will be returned. The first 25 values contain data from the transmission pulse and should be ignored (this means that the maximum height measurable by the sonar sensor is the mounting height minus 25cm). It should be remembered that the data is returned with the last data item representing the signal intensity returned from ground level. For example the following data was collected with the sensor mounted at 70cm above ground level:

Figure 1: The geranium plant used to generate example data.

581, 692, 720, 727, 715, 707, 706, 695, 686, 674, 660, 647, 641, 622, 591, 560, 515, 465, 389, 338, 319, 298, 286, 281, 279, 279, 278, 276, 275, 275, 275, 275, 274, 274, 281, 288, 282, 280, 276, 275, 274, 273, 273, 273, 273, 273, 273, 273, 273, 272, 284, 297, 298, 326, 374, 412, 438, 448, 451, 436, 382, 352, 356, 360, 365, 391, 418, 427, 438, 442
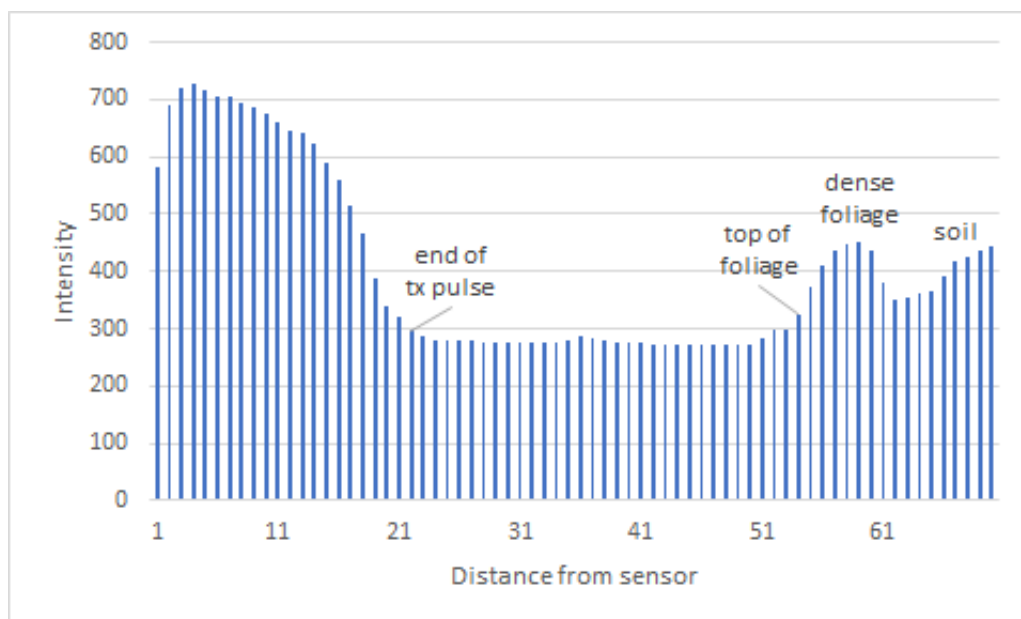
Figure 2: The top of the plant is at around point 52 which is 18cm above datum when the mounting height is 70cm (70 − 52 = 18). The density of the foliage can also be seen to be greater (higher signal intensity) further down the plant and reaches a maximum around point 59 which is 11cm above datun (70 − 59 = 11). In this test the infra-red sensor returned a height of 19cm.

3   Communication

The sensor communicates using a simple 3.3V asynchronous serial protocol designed for connection to a UART on microcontroller systems or a USB to TTL cable ("FTDI cable") for USB host equipped devices such as laptop and desktop PCs.

    The default baud rate is 4800, but this can be configred as described below up to a maximum speed of 57600. Changes to the baud rate and other configurable parameters are retained after power-down.

    The protocol consists of single character codes which are followed by arguments when setting internal parameters. Upper case character codes are used for commands which change the state of the sensor in some way, such as configuring sensor parameters or gathering new data. Lower case characters are used for commands which do not change the state of the sensor, such as reading data or configuration parameters from the sensor.

    All commands return a value or character to indicate that they are complete, and it is best to wait for the response before attemtping to send further commands. The "?" is used to indicate that a command was received that was not understood by the sensor, and the "!" to indicate succesful completion of an action. Configuration commands echo the command to indicate successful completion of the configuration update. After power-on the sensor will return a "!" when it is ready to receive commands.

3.1 Command Protocol

Protocol summary (see 3.2 and 3.3 for detailed descriptions of command usage):

Command	Response	Description
"K *int* $\backslash r \backslash n$"	Canopy height	Trigger sonar and IR sensors to measure canopy height
"L *int* $\backslash r \backslash n$"	Canopy height	Trigger sonar sensor only to measure canopy height
"S$\backslash r \backslash n$"	"!$\backslash r \backslash n$"	Triggers sonar data collection
"s$\backslash r \backslash n$"	Sonar data array	Returns sonar data
"I$\backslash r \backslash n$"	"!$\backslash r \backslash n$"	Triggers IR data collection
"i$\backslash r \backslash n$"	IR height measurement	Returns infra-red data
"B *int* $\backslash r \backslash n$"	"B$\backslash r \backslash n$"	Set baud rate
"b$\backslash r \backslash n$"	Current baud rate	Read baud rate
"H *int* $\backslash r \backslash n$"	"H$\backslash r \backslash n$"	Set height offset
"h$\backslash r \backslash n$"	Current height offset	Read height offset
"M *int* $\backslash r \backslash n$"	"M$\backslash r \backslash n$"	Set sonar threshold
"m$\backslash r \backslash n$"	Current sonar threshold	Read sonar threshold
"R *int* $\backslash r \backslash n$"	"R$\backslash r \backslash n$"	Set sonar repetitions
"r$\backslash r \backslash n$"	Current sonar repetitions	Read sonar repetitions
"T *int* $\backslash r \backslash n$"	"T$\backslash r \backslash n$"	Set sonar resolution
"t$\backslash r \backslash n$"	Current sonar resolution	Read sonar resolution
"J *int* $\backslash r \backslash n$"	"J$\backslash r \backslash n$"	Set infra-red repetitions
"j$\backslash r \backslash n$"	Current infra-red repetitions	Read infra-red repetitions

3.2 Sensing commands

Detect crop height using both sonar and infra-red sensors: The sensor is able to take multiple readings using both sensors and to find the highest reading. This can be useful to find the the tallest part of the crop visible to the sensor, particularly when wind action is causing the crop to move significantly. To trigger this action send a "K" followed by a number between 1 and 100 to set the number of repetitions to be made. For example the string "K 10$\backslash r \backslash n$" will cause the sensor to take ten readings from each sensor and return the maximum height detected in centimetres. Each repetition takes around 1000 milliseconds, when the sonar and infra-red repetitions are set to 1, larger numbers of repetitions for the sensors (set using "R" and "J") will increase this time proportionately.

Command:	Response:	Effect:
(example) "K 10$\backslash r \backslash n$"	(example) "24$\backslash r \backslash n$"	Trigger sonar and IR sensors

Trigger crop height detection using only sonar measurement: To detect the crop height using only the sonar sensor send the string "L$\backslash r \backslash n$". This command takes a sonar reading and finds the height of the crop by looking for the increase in signal strength in the reflected ultrasound. The threshold value is set to 20% by default but can be adjusted using the using the "M" command (see configuration commands below).

Command:	Response:	Effect:
(example) "L 10$\backslash r \backslash n$"	(example) "24$\backslash r \backslash n$"	Trigger sonar sensor

Trigger sonar measurement: To trigger the acquisition of sonar data send the string "S$\backslash r \backslash n$". This will cause the sensor to make sonar measurements and collate the results ready for extraction by the user. When data collection is complete the string "!$\backslash r \backslash n$" will be returned. The number of samples that are taken and averaged over can be set as described in the configuration section below. The default number of repetitions is 1. Decreasing the number of repetitons will decrease the time between triggering a measurement and being able to read the new data from the sensor. Each repetition takes approximately 700ms to complete, so with 10 repetitions the sensor will require around 7s before it will be able to respond to a request for data. While the sensor is making measurements it will not respond to commands.

Command:	Response:	Effect:
"S$\backslash r \backslash n$"	"!$\backslash r \backslash n$"	Triggers sonar data collection

Trigger IR measurement: To trigger the acquisition of infra-red data send the string "I$\backslash r \backslash n$". This will cause the sensor to make sonar measurements and collate the results ready for extraction by the user. When data collection is complete the string "!$\backslash r \backslash n$" will be returned. The number of samples that are taken and averaged over can be set as described in the configuration section below. The default number of repetitions is 10. Decreasing the number of repetitons will decrease the time between triggering a measurement and being able to read the new data from the sensor. Each repetition takes up to 25ms to complete, so with 10 repetitions the sensor will require around 250ms before it will be able to respond to a request for data. While the sensor is making measurements it will not respond to commands.

Command:	Response:	Effect:
"I$\backslash r \backslash n$"	"!$\backslash r \backslash n$"	Triggers infra-red data collection

Read sonar: To read the sonar data from the sensor send the string "s$\backslash r \backslash n$". This will cause the sensor to stream a comma separated list of sonar intensity values terminated by "$\backslash r \backslash n$" out over the serial port. The number of values returned will be set by the combination of sonar resolution value (set to 1cm by default) and the maximum range value (set to 3m by default). Thus by default a stream of 300 values will be sent out over the serial port. These values represent the intensity of the ultrasound reflected at each range and may be used for detailed modelling and assessment of the crop canopy structure.

Command:	Response:	Effect:
"s$\backslash r \backslash n$"	(example) "0.0, 0.0, 0.15, 0.9, 1.95 ... 0.19$\backslash r \backslash n$"	None

Read IR: To read the infra-red data from the sensor send the string "i$\backslash r \backslash n$". This will cause the sensor to return a single value terminated by "$\backslash r \backslash n$" which is the tallest reliable reading in cms as measured from ground-level by the infra-red sensor which represents the highest point detected in the crop canopy.

Command:	Response:	Effect:
"i$\backslash r \backslash n$"	(example) "93$\backslash r \backslash n$"	None

3.3 Configuration commands

Set/get baud rate: To set the baud rate to 57600 send the string "B 57600$\backslash r \backslash n$". This will cause the sensor to return "B$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to an unsupported baud rate). The sensor will only accept the following baud rate values: 4800, 9600, 19200, 38400, 57600.

To read the baud rate send the string "b$\backslash r \backslash n$". This will cause the sensor to return the current baud rate such as (for example) "9600$\backslash r \backslash n$".

Command:	Response:	Effect:
(example) "B 57600$\backslash r \backslash n$"	"B$\backslash r \backslash n$"	Set baud rate to 57600
"b$\backslash r \backslash n$"	(example) "57600$\backslash r \backslash n$"	None

Set/get mounting height: To set the sensor mounting height send the string "H 100$\backslash r \backslash n$". This will cause the sensor to return "H$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to a badly formatted string). The sensor interprets the integer value following the the command as the height of the sensor above the ground in cm.

To read the mounting height send the string "h$\backslash r \backslash n$". This will cause the sensor to return the current mounting height such as (for example) "65$\backslash r \backslash n$".

Command:	Response:	Effect:
(example) "H 100$\backslash r \backslash n$"	"H$\backslash r \backslash n$"	Set height offset to 100cm
"h$\backslash r \backslash n$"	(example) "65$\backslash r \backslash n$"	None

Set/get sonar threshold value: To set the threshold value for the sonar to register the top of the crop to 20% above the minimum reading send the string "M 20$\backslash r \backslash n$". This will cause the sensor to return "M$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to a badly formatted string). The sensor will only accept values between 1 and 100.

To read the sonar threshold send the string "m$\backslash r \backslash n$". This will cause the sensor to return the current threshold such as (for example) "20$\backslash r \backslash n$".

Command:	Response:	Effect:
(example) "M 20$\backslash r \backslash n$"	"M$\backslash r \backslash n$"	Set sonar threshold to 20%
"m$\backslash r \backslash n$"	(example) "20$\backslash r \backslash n$"	None

Set/get sonar repetitions: To set the number of sonar readings to be made to 20 send the string "R 20$\backslash r \backslash n$". This will cause the sensor to return "R$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to a badly formatted string). The sensor will only accept values between 1 and 100.

To read the number of sonar repetitions send the string "r$\backslash r \backslash n$". This will cause the sensor to return the current number of sonar repetitions to be made such as (for example) "15$\backslash r \backslash n$".

Command:	Response:	Effect:
(example) "R 20$\backslash r \backslash n$"	"R$\backslash r \backslash n$"	Set sonar repetitions to 20
"r$\backslash r \backslash n$"	(example) "15$\backslash r \backslash n$"	None

Set/get sonar resolution: To set the resolution of the sonar reading data send the string "T 5$\backslash r \backslash n$". This will cause the sensor to return "T$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to a badly formatted string). In this example each sonar data reading will represent the amplitude of the signal in a 5cm window. In calculating this amplitude a series of readings will be integrated and the mean generated. The sensor will only accept values between 1 and 100.

To read the sonar resolution send the string "t$\backslash r \backslash n$". This will cause the sensor to return the current sonar resolution such as (for example) "2$\backslash r \backslash n$", which represents a 2cm resolution.

[IMAGE]

Command:	Response:	Effect:
(example) "T 5$\backslash r \backslash n$"	"T$\backslash r \backslash n$"	Set sonar resolution to 5cm
"t$\backslash r \backslash n$"	(example) "2$\backslash r \backslash n$"	None

Set/get IR repetitions: To set the number of infra-red readings to be made to 20 send the string "J 20$\backslash r \backslash n$". This will cause the sensor to return "J$\backslash r \backslash n$" if the command was successful and "?$\backslash r \backslash n$" if the command failed (for example due to a badly formatted string). The sensor will only accept values between 1 and 100.

To read the number of sonar repetitions send the string "j$\backslash r \backslash n$". This will cause the sensor to return the current number of sonar repetitions to be made such as (for example) "15$\backslash r \backslash n$".

Command:	Response:	Effect:
(example) "J 20$\backslash r \backslash n$"	"J$\backslash r \backslash n$"	Set infra-red repetitions to 20
"j$\backslash r \backslash n$"	(example) "15$\backslash r \backslash n$"	None