# IoT node design

## Overview

The Internet of Things (IoT) node is a combination of a microcontroller and hardware sensors that is installed in a GrowCube to record data automatically. This document describes the proposed components and associated costs.

## Microcontroller

The main requirements for the microcontroller are to

* provide connections for an appropriate range and number of sensors
* communicate over WiFi
* provide user interaction and feedback
* operate independently of a fixed power supply
* enable the local storage of data
* consume as little power as possible
* have a small physical footprint

The device selected is the [LilyGo TTGO T5](http://www.lilygo.cn/prod_view.aspx?TypeId=50061&Id=1393&FId=t3:50061:3) (Figure 1) which includes an e-paper display, programmable button and an integrated SD card reader.



66.3mm

36.8mm

e-Paper display

Programmable button

Reset button

Power switch

Micro USB

Figure 1: TTGO T5 microcontroller

The T5 is powered by a 1000mAh lithium polymer (LiPo) battery which would power the device for around 36 hours at maximum consumption levels – i.e. assuming constant display refreshing during that time. Between image refreshes, the display consumes no power at all, and under normal operating conditions, one battery recharge is expected to last for up to a month. Tests will be carried out during development to provide a more precise estimate.

The device will be packaged in a 3D printed enclosure (see below) that will protect the electronics while providing access to the controls shown in Figure 1 and for making connections to the sensors.

## Sensors

The proposed parameters that the IoT node will measure are

* Air temperature
* Relative humidity
* Light intensity
* Ambient noise level
* Water level
* Soil pH
* Soil electrical conductivity
* Soil moisture
* Soil temperature

The following sections provide details of the recommended sensors in each case.

### Air temperature and relative humidity

These two quantities are often measured by a single device and the recommended option for this project is the [Sensirion SHTC3](https://www.sensirion.com/en/environmental-sensors/humidity-sensors/digital-humidity-sensor-shtc3-our-new-standard-for-consumer-electronics/). This sensor is pre-calibrated and provides an accuracy of ±2% for relative humidity and ±0.2°C. It comes packaged in various ways, and the one shown in Figure 2 is mounted on a circuit board with a mounting hole. This is the version that would be used if the sensors are individually enclosed. Please see the ***Enclosures*** section for further details.

A picture containing electronics

Description automatically generated

Figure 2: Packaged SHTC3 temperature and humidity sensor

### Light intensity

The proposed sensor for light intensity is the [Rohm BH1750FVI](https://datasheetspdf.com/pdf-file/679289/Rohm/BH1750FVI/1) which provides output in lux (lx) with an accuracy of ±1.2 lx. For reference, ambient daylight typically ranges between 10000 and 25000 lx. The sensor is pre-calibrated and comes packed as the GY-30 board shown in Figure 3.

A picture containing text, electronics, circuit

Description automatically generated

Figure 3: GY-30 light intensity sensor board

### Ambient noise level

A noise level sensor is essentially a microphone that only detects sound wave amplitude rather than frequency. The device proposed for Dandelion is the board shown in Figure 4 which is based around a Texas Instruments [LM393 amplifier](https://www.ti.com/lit/ds/symlink/lm393.pdf?ts=1641498227260&ref_url=https%253A%252F%252Fwww.ti.com%252Fproduct%252FLM393) chip. No accuracy figures are available and the device may need calibration.

A close-up of a circuit board

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Figure 4: Sound sensor based on the LM393 amplifier

### Water level

This sensor assumes that the GrowCube will have a reservoir of water for each level that is independent of the individual seedling locations. It essentially duplicates the on-board water level gauge. The device proposed is very basic, relying only on the resistance between metal traces on a board as shown in Figure 5. Calibration is required for accurate readings. It is possible that the metal traces may be prone to corrosion if used over long periods.

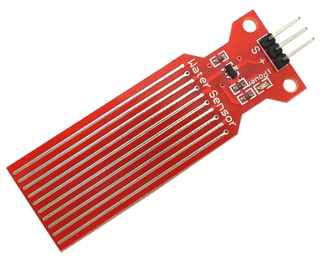


Figure 5: Water level sensor

### Soil moisture

There are two main types of soil moisture sensor. The resistive type work on a similar principle to the water level sensor above and are prone to corrosion. The capacitive type do not have exposed electrical connections, and are usually preferred. The model proposed here, shown in Figure 6, is built using the Texas Instruments TL555I timer chip which allows the device to work at a voltage that is compatible with the T5. This sensor requires calibration.

Graphical user interface

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Figure 6: Capacitive soil moisture sensor

### Soil temperature

Measurements of soil temperature are required in order to apply a correction to conductivity values (see later section). It can also be an interesting value in its own right. The device based on the [Maxim DS18B20](https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf) digital thermometer chip shown in Figure 7 is pre-calibrated.

A picture containing earphone, cable, adapter

Description automatically generated

Figure 7: DS18B20 waterproof soil temperature sensor

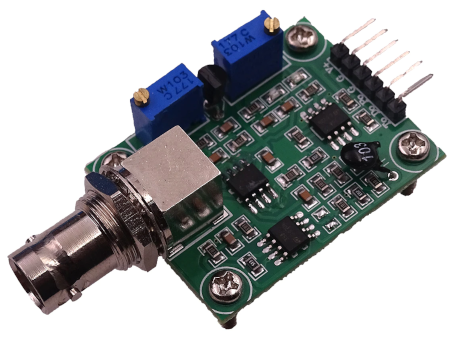
### Soil pH

Typical pH sensors are relatively expensive in comparison to the more sensors above. They are composed of a probe and a signal processing board that are linked by a cable. One of the most popular pH sensors available is the [Gravity kit](https://www.dfrobot.com/product-2069.html) which costs around £26. A second issue with standard pH probes is that they are around 300mm in length which would not fit comfortably inside the GrowCube. Finally, the majority of pH sensors operate at 5V whereas the T5 operates at 3.3V. Sometimes, a sensor may still operate at the lower voltage, and a unit has been ordered so that tests can be carried out to evaluate the feasibility of using 3.3V.

Zimmer and Peacock (Z&P) offer a [solid state pH probe](https://www.zimmerpeacocktech.com/products/electrochemical-sensors/ph-sensor/) which is much smaller (25.4 x 7 x 0.625 mm) and cheaper than the standard ones. However, use the Z&P probes would entail the construction of bespoke connection cables based on the BNC adapter shown in Figure 8.

In the case where the cheaper signal processing boards can be made to work at 3.3V, an installed pH sensor would consist of the items listed below and pictured in Figure 8. These sensors would require calibration using solutions of known pH.

1. Z&P solid-state probe
2. Connection clip
3. BNC adapter
4. Signal processing board



a

b

c

d

Figure 8: pH sensor components

### Soil electrical conductivity

The electrical conductivity (EC) of soil can be measured easily using the same principle as the water level sensor described above. Two electrodes are placed into the soil and the conductivity depends on the resistance between them adjusted for temperature. Commercial EC sensors can be very expensive. The proposal here is to construct bespoke EC sensors from basic materials and to perform the appropriate calculations in software using [published relationships](https://www.metergroup.com/en/meter-environment/education-guides/soil-electrical-conductivity-complete-guide-measurements). These DIY sensor will require calibration by comparing the readings with a commercial EC probe. The essential components for the DIY sensors are a pair of stainless steel rods mounted in a robust enclosure. Because the temperature value should be measured close to the electrodes, the soil temperature sensor described above would also be mounted in the same enclosure.

### Costs

The estimated costs per unit for each of the sensors described above are shown in Table 1. These figures are based on information available at the time of writing and include costs for shipping, customs and VAT as far as possible. Enclosure costs are not included at this stage except for the EC sensor where a rough estimate is used.

The cost of the pH sensor represents the best case scenario. If tests determine that the standard signal processing boards will not operate at 3.3V, the only option would be use the Gravity board which is the only one available that is designed to work at the lower voltage. The Gravity board is usually only supplied as part of an entire kit; however a quote for just the board has been requested.

Assuming that all sensors will be installed in all three levels of each GrowCube, the total cost would be £17734.50 assuming a total of 150 GrowCubes.

An alternative distribution would be to include sound, pH and EC sensors in only one level of each GrowCube. In that case the total would be £8468.

Please note that the original project budget included costs for the IoT nodes including the microprocessors and enclosures. Of that budget item, approximately £3500 is available to spend on sensors.

Table 1: Sensor cost estimates

|  |  |  |
| --- | --- | --- |
| Sensor | Cost per unit (£) | Link |
| SHTC3 | 1.92 | https://www.aliexpress.com/item/1005003511936737.html |
| GY-30 | 1.65 | https://uk.banggood.com/10pcs-GY-30-3-5V-0-65535-Lux-BH1750FVI-Digital-Light-Intensity-Sensor-Module-p-1209085.html?cur\_warehouse=CN |
| LM393 | 0.37 | https://www.aliexpress.com/item/1005002291568348.html |
| Water level | 0.24 | https://uk.banggood.com/50pcs-DC-3V-5V-20mA-Rain-Water-Level-Sensor-Module-Detection-Liquid-Surface-Depth-Height-For-Geekcreit-for-Arduino-products-that-work-with-official-Arduino-boards-p-1633677.html?gmcCountry=GB&cur\_warehouse=CN |
| Moisture | 0.46 | https://www.aliexpress.com/item/4001131897353.html |
| DS18B20 | 1.27 | https://www.aliexpress.com/item/32827810300.html |
| pH | 30.00 | https://www.zimmerpeacocktech.com/products/electrochemical-sensors/ph-sensor/  https://www.zimmerpeacocktech.com/products/accessories/three-way-spe-connector/  https://www.aliexpress.com/item/32903352013.html  https://www.ebay.co.uk/itm/222532763908 |
| EC | 3.50 | https://www.machinemart.co.uk/p/37279-left-d235/  https://cpc.farnell.com/camdenboss/ctbp1050-2/terminal-block-90deg-16a-2-pole/dp/CN20831 |
| Total | 39.41 |  |

## Enclosures

The T5 microcontrollers will be housed in 3D printed enclosures similar to the one shown in Figure 9 which has been sourced from [3dmdb.com](https://3dmdb.com/en/3d-model/case-for-ttgo-t5-esp32-epaper-by-megacadler/8344093/?q=ttgo+t5+battery). The design will be adapted for the requirements of the Dandelion project.

Calendar

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Figure 9: Example T5 enclosure from 3dmdb.com

The DIY EC sensor would also require a bespoke housing in order to mount the electrodes and temperature sensor. A further enhancement to the system would be to design enclosures for each of the other sensors so that they can be connected together easily. If the budget allows, this approach would greatly simplify the connection of the devices and would help to protect the sensors from accidental damage.

## Installation

The schematic in Figure 10 illustrates the position of the microcontroller and sensors in the GrowCube. The graphic assumes that sensors will have individual enclosures.

T5 microcontroller

Sensor group

Figure 10: Schematic representation of GrowCube installation

Sensor groups will be connected to the T5 via a single multicore cable to reduce the amount of exposed wiring. The groups will be daisy-chained, as will the sensors within a group. There are several aspects of the physical installation that can only be finalised once an example GrowCube is available. These include the length and precise route of the connecting cable, and the specific location of the sensors within a group. It is assumed that the sensors will need to occupy one or more of the seedling positions in each level of the GrowCube. Some sensors, such as the pH sensor and the EC sensor may require a seedling position to themselves while it may be possible to group other sensors together if they only need the seedling position for stability.