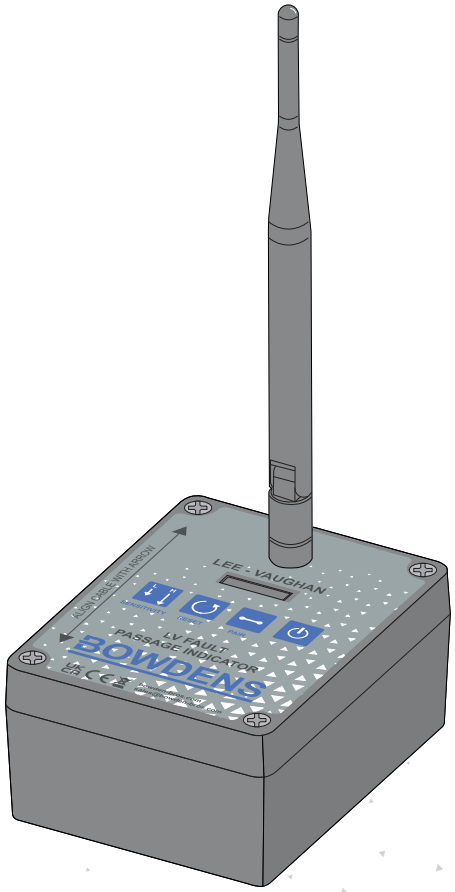
BOWDENS

# LV UNDERGROUND FAULT PASSAGE INDICATOR (LV FPI)




## A PORTABLE INSTRUMENT DESIGNED TO FIND FAULTS ON LV CABLE NETWORKS

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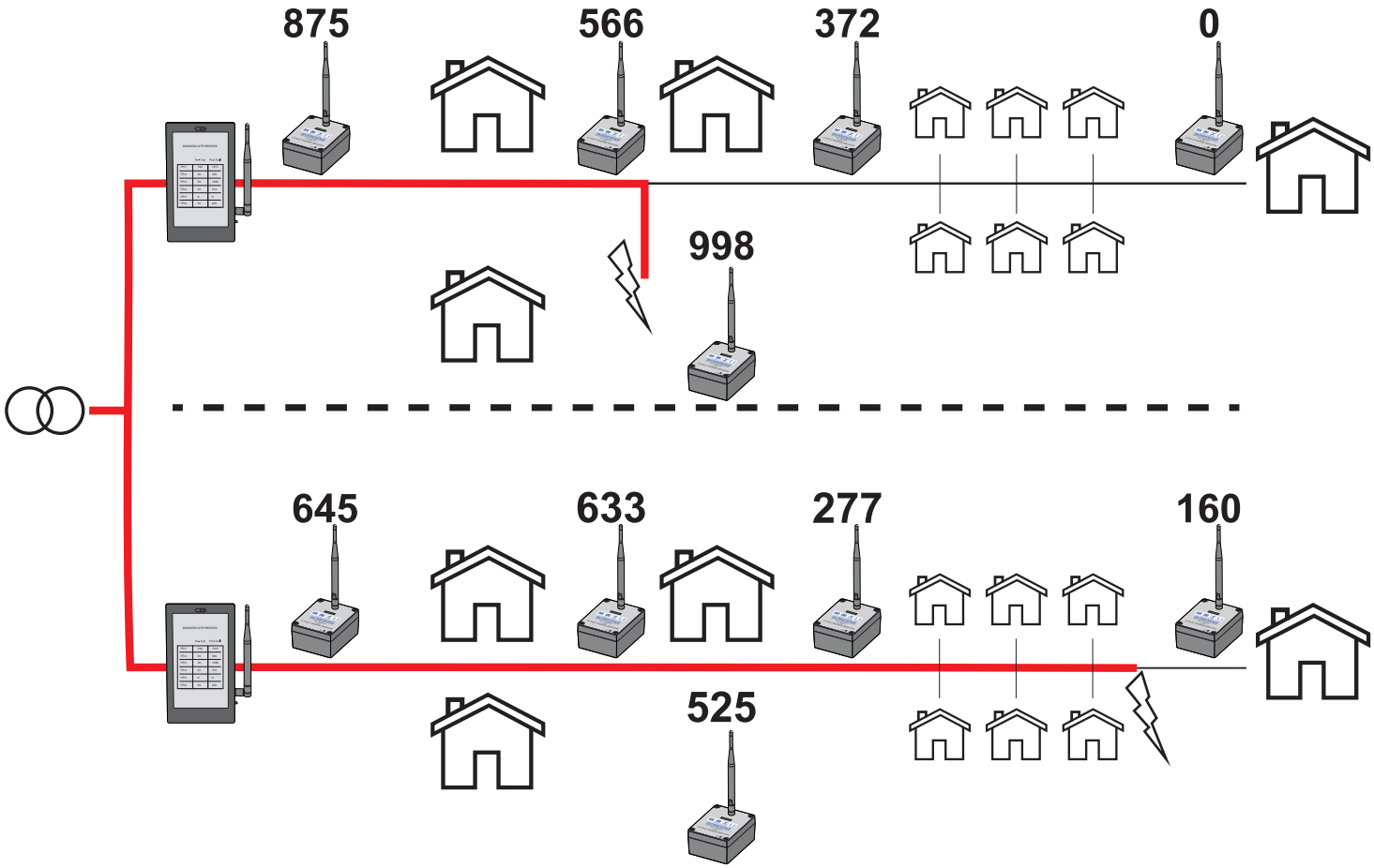
## 1.0 OVERVIEW

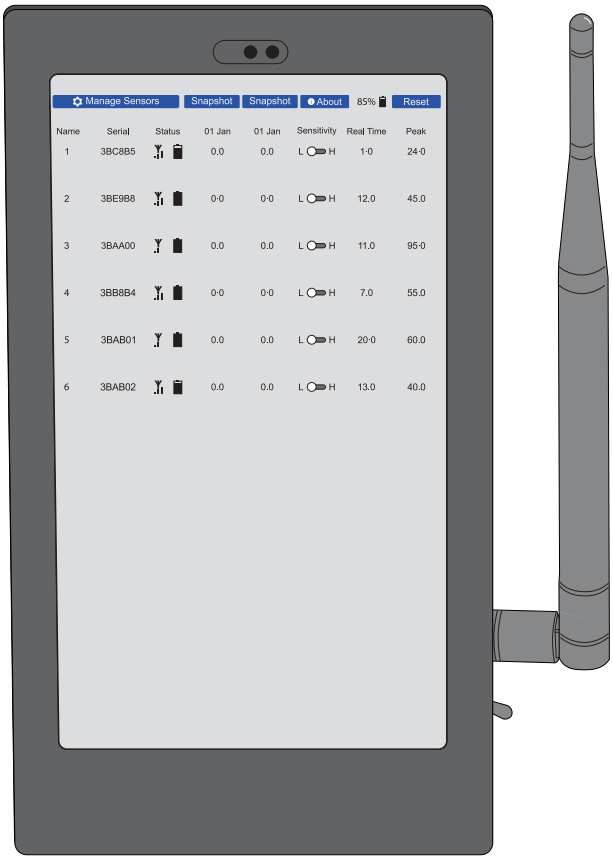
This system is intended to aid the tracing of the path a fault current flows down a low-voltage cable and to help identify where a fault is. There are six sensors in a standard set, and they record the peak current that has been detected flowing down the buried cable over which they are placed. The measurement is by the magnetic field which falls away with increasing distance, the actual measurement is an indication of fault current from 0-999.9 but which has no units.

A typical use would be to place sensors over strategic points on the path of the cable to try to identify how far down the cable the fault might be, and on which branch the fault is, where the cable feeds multiple users. The cable could then be energised, or if the fault causes circuit-breakers to open rapidly, a “rezap” could be applied. At this point the engineer wants to see measurements of all the sensors, and possibly reset them prior to doing another “rezap”. The aim of this equipment is to allow the engineer to monitor and control all of the sensors from a central location using a “Concentrator”, so they do not need to visit all of the sensors individually.




The diagram above represents two identical circuits with different fault locations, and different fault impedances which might produce the readings shown. The maximum readings will appear before the fault, with a noticeable reduction after the fault. We would anticipate some field to be recorded on healthy spurs between the fault and the source, but always considerably less than that recorded on the main feeder.

The long-range LoRa radio standard is used, transmitting at 868 MHz. In order to comply with radio licensing requirements, messages are only sent roughly once per minute. The range depends very much on local circumstances, but where line-of-sight is possible between sensors and Concentrator, a range of several hundred metres is feasible. Placement of sensors at strategic locations over the faulty cable is a matter that relies upon the skill of the engineering team, and their understanding of the route of the cable and the characteristics of the fault. As such, it is beyond the scope of this document which is only intended to explain the radio-communication capability and new features of the LV-FPI.



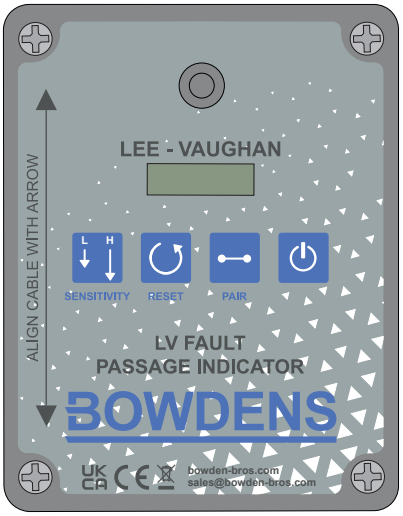

When switched on, all LV FPIs report back to a dedicated tablet style receiver called the Concentrator where the current readings of electromagnetic fields are recorded. When the circuit is energised fault current will flow, and each FPI will report on the field it sees at the time of fault to the tablet over a radio link.

Each LV FPI has its reading recorded as a maximum on the LCD screen.

## 2.0 MODEL FEATURES

- Traces fault currents by recording peak current along buried cables.
- Uses six sensors to detect peak current values.
- Allows energizing and "rezapping" of the cable after fault identification.
- Centrally monitors sensors using a "Concentrator," eliminating manual visits.
- Uses LoRa radio at 868 MHz for communication with variable range.

## 3.0 OPERATION
## 3.1 SENSORS




The sensors are based on the Bowdens “LV Underground Fault Tester” with the addition of radio communication circuitry to allow them to send the measurements back to a “Concentrator” unit which the engineer keeps at the central location. The current-detecting coil is at the bottom of the unit, hence the sensor should be placed upright above the buried cable.

On each sensor there are four buttons:

- Sensitivity – this toggles between a full-scale of 9999 (low sensitivity) and 999.9 (high-sensitivity)
- Reset – clears the peak reading ready for another test. Holding in the reset button makes the unit display the Real-Time reading, which can be helpful for positioning the sensor over a live cable.
- Pair – this is used to associate the sensor with a particular Concentrator. As long as the sensors are kept as a set with their Concentrator, this should not be needed in normal use. To minimise the risk of entering pairing mode, a long press is required to pair.
- Power On/Off – a short press of this button turns the unit on. A longer press of about two seconds will shutdown the sensor. Note: This is important to maximise battery life.

Both Sensitivity and Reset may also be operated from the Concentrator.

Sensor Display

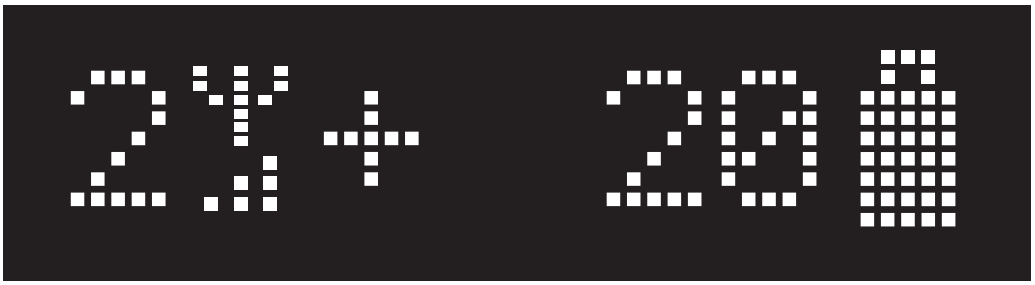


Figure 1

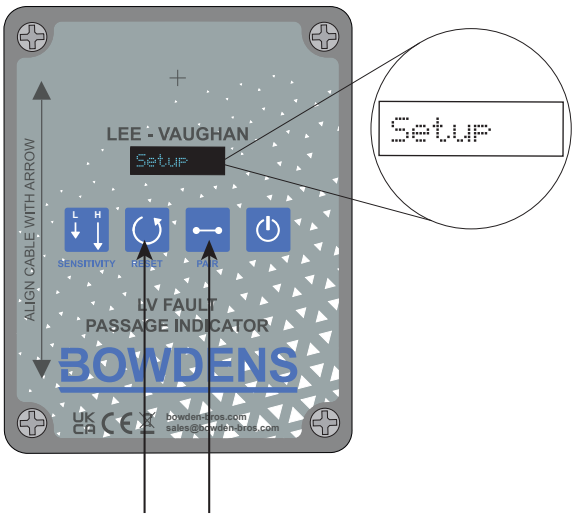
The display is a small OLED screen, shown in Figure 1. On the left is a number, from one to six, to allow the engineer to identify which sensor is which. All sensors have a unique serial-number, but this is difficult to keep track of, so the Concentrator assigns a single-digit number to each sensor. Next is an icon showing the signal strength. It consists of a picture of an antenna with up to four bars below it. If the antenna has a cross beneath it, this means that the sensor has not been able to contact the Concentrator. This could mean that it is out-of-range, or the Concentrator is turned off. Note: It takes about a minute for communications to be established between the sensor and the Concentrator.

The “+” symbol is only shown when the real-time reading is at least half the peak reading. Then follows the reading, either 0-9999 or 0-999.9 depending on sensitivity setting. In this case a peak field of 20 has been recorded.

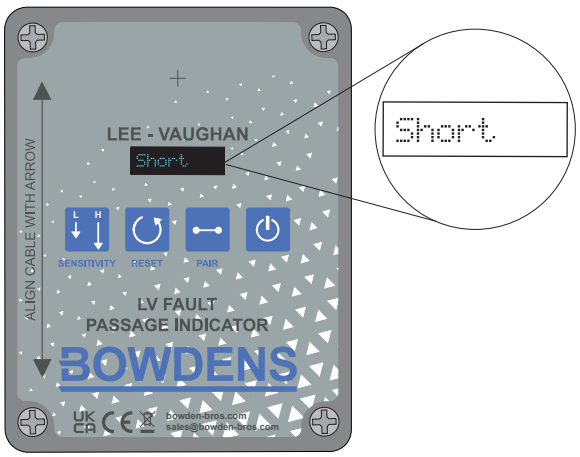
Finally we have the battery symbol, giving an indication of how much battery-life remains. In order to maximise battery life, the display turns off after about five minutes. You may press any button to wake-up the display. But note that the unit remains live, actively measuring and sending the measurement back to the Concentrator even when the display is blanked. It is important to ensure every sensor is turned off once all measurements are complete.

### 3.2 MANUALLY ADJUSTING THE SENSORS

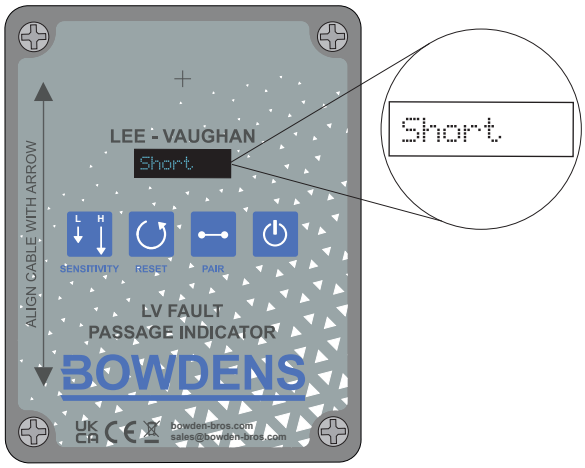
To manually adjust the sensors, hold down the Reset and Pair buttons for a few seconds to access the Setup mode.



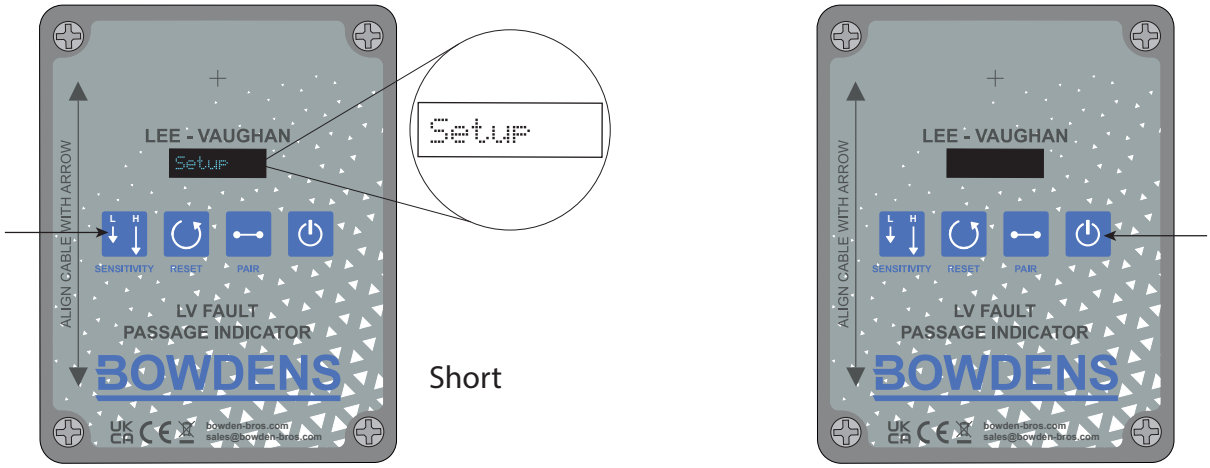

When in Setup mode, pressing the Sensitivity button will cycle between the different modes, Short and then back to Setup. The Reset button will "do" or "change".



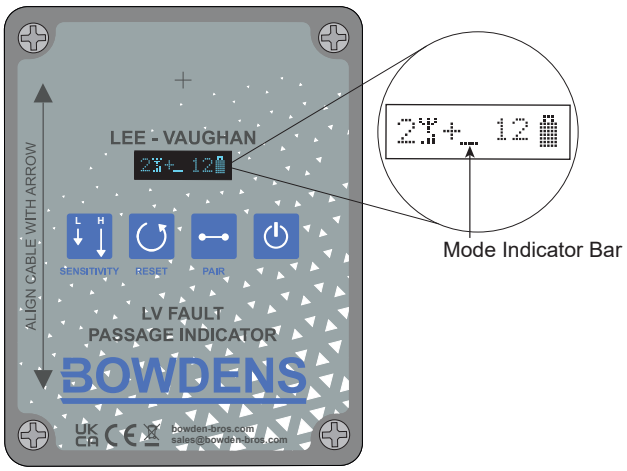

Pressing the Power button at Short will cycle between Short, 30ms_Lo, 30ms_Hi and 50ms_Hi. These are the fault sensing algorithms and are explained in section 3.4 Manage Sensors and Pairing

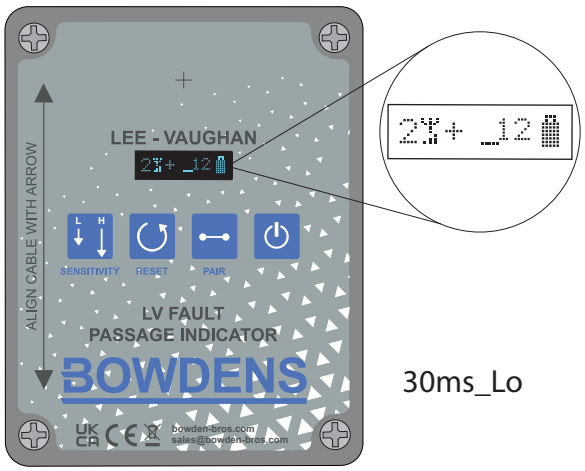



Pressing the Sensitivity button at this point will get you back to Setup. Pressing the Power button will close the Setup window and return to normal operation.

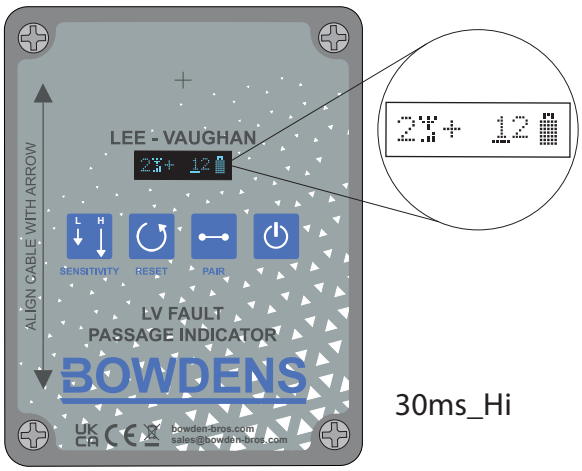


To understand what mode you are in, check where the underlined symbol appears. See below to understand the different modes.

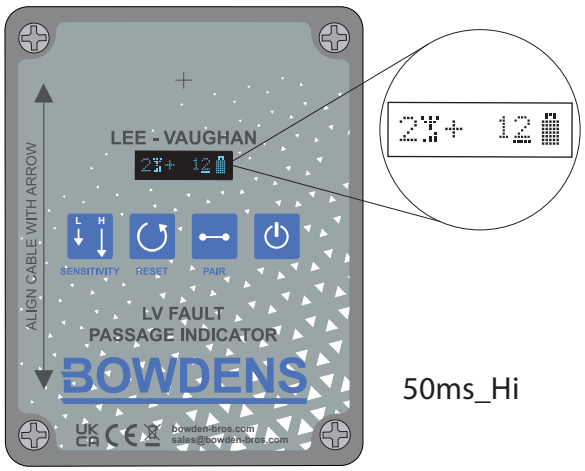



30ms_Lo




30ms_Hi




50ms_Hi

### 3.3 CONCENTRATOR

The Concentrator is built around an Android tablet computer, with the addition of a radio communication module to allow it to receive messages from each of the sensors. An image of the tablet case is shown in Figure 2:

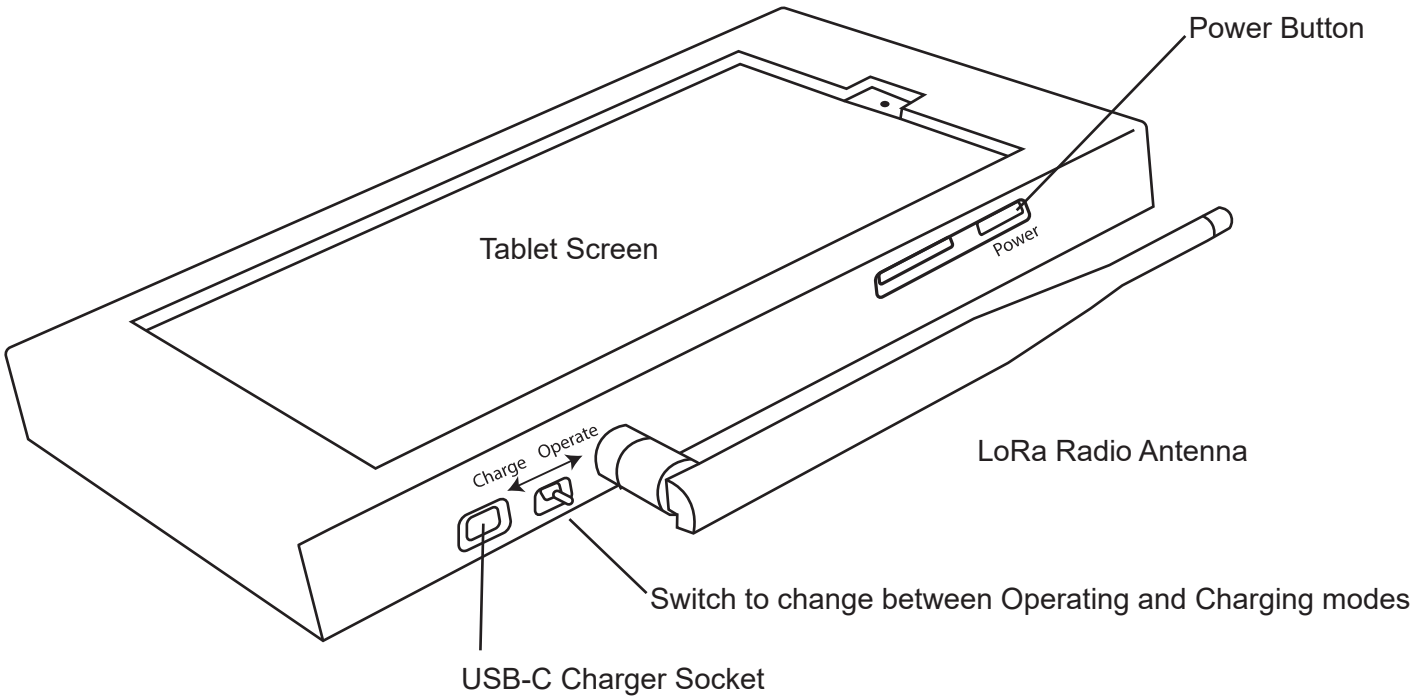



Figure 2: Concentrator - Android tablet with LoRa radio

**IMPORTANT:** To use tablet for fault finding ensure switch is set to ‘Operate’.
The tablet is turned on by a long press on the power button, followed by a swipe on the touchscreen. If the small switch is in the Charge position, this might take you to the standard Android “home” screen, at which point the LV-FPI app may be launched by tapping its icon, which is shown in Figure 3. But if the toggle switch is in the “Operating” position, the LV-FPI App should start automatically, and you will see something like Figure 4.


Figure 3: Android tablet home screen

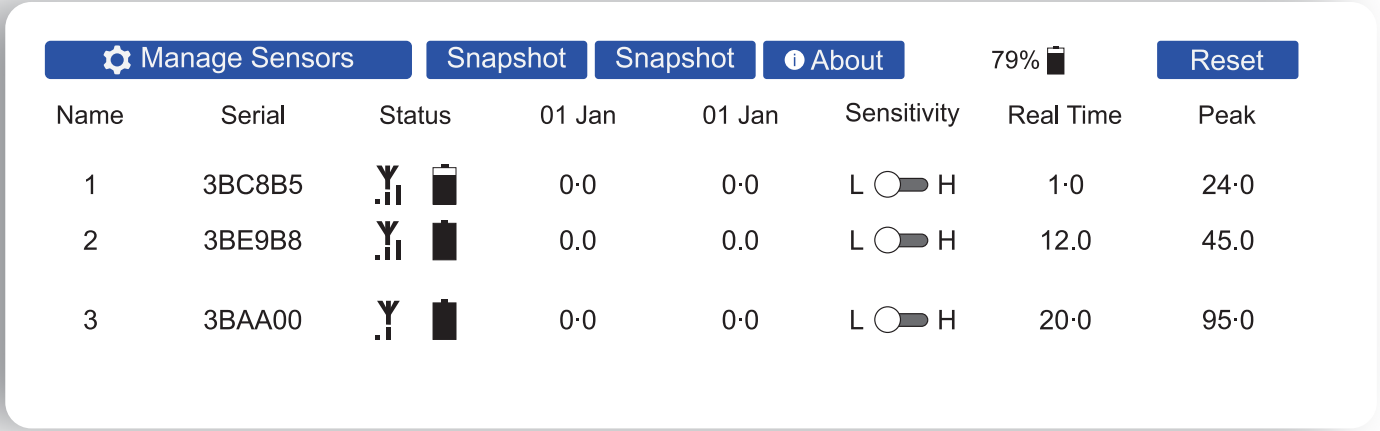



Figure 4: LV-FPI App main screen

The main screen in Figure 4 consists of a row of buttons along the top, then a table of sensor data and finally a log of recent events. This image shows only three sensors; a full kit will have six. The sensors here are named 1, 2 and 3, followed by their serial-numbers. The status field shows radio signal-strength and battery-condition for each sensor. After that are two “snapshot” columns. These show the peak value recorded when the corresponding Snapshot button is pressed. Then we have the sensitivity switch for each sensor. You may tap on each slider to change between high and low for the corresponding sensor. Note that in Low sensitivity readings may run from 0 to 9999, but in high-sensitivity they may only go from 0 to 999.9.

### 3.4 MANAGE SENSORS AND PAIRING

As said before, pairing is not something that will be done often. Normally a kit of six sensors should remain paired to their associated Concentrator. Sensors will only communicate with the Concentrator they are paired with. A sensor can only be paired with a single Concentrator. A kit consisting of six sensors and a Concentrator will be supplied with all the sensors already paired with the Concentrator. If a particular fault needs more than six sensors, it is possible to add others and pair them to the Concentrator being used. Note that if an engineer chooses to “borrow” them from another kit, it is vitally important that they are re-paired back to that kit immediately after use.

To allow sensors to be paired, a Concentrator must first be put into pairing mode. To do this, press the “Manage Sensors” button at the top-left of the screen. This will bring up the Manage Sensors window. Pairing must be turned on by operating the slider as shown in Figure 5. Note that a Concentrator will only accept pairing requests from sensors while this screen is shown and the “Allow Pairing” slider is on. Any sensors to be paired must be brought close to the Concentrator, and turned on. Press and hold the “Pairing” button on the sensor unit until the sensor screen shows “Pair?N/Y”. With that message showing, press the sensor “Power On/Off” to confirm pairing mode, at which point the screen will show “Pairing”.

The pairing process can take a couple of minutes, longer if there is more than one sensor to be paired. If a sensor sees a Concentrator that is not in pairing mode, it will momentarily show the message “CPair?” to remind the engineer to double-check the concentrator's setting. As a sensor is paired, the sensor's screen will revert to normal, and the serial number will show on the Concentrator's screen beneath the “Allow pairing” message. Once all the desired sensors are paired, close the window by tapping on “Done” or outside of the window.

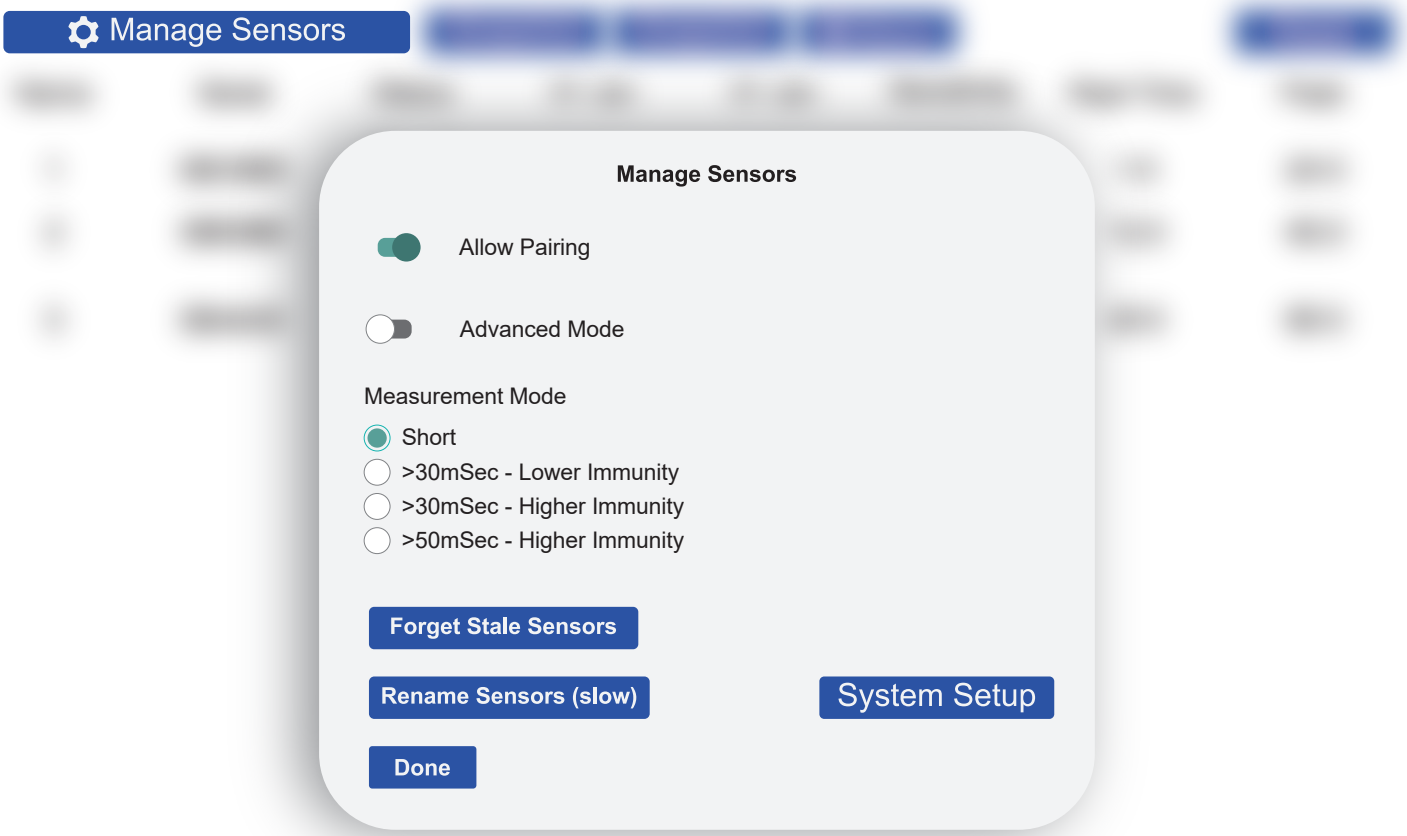



Figure 5: Manage Sensors screen, with Pairing enabled

There are four measurement modes for the sensors:

Short
Shorter Pulse Detection. Lower noise immunity. For faults where the circuit breaker opens immediately after being re-closed onto a fault.

>30mSec - Lower Immunity
Faults of over 30mS. Lower noise immunity. This is looking for a fault of over 30mS duration. It is more sensitive than the higher immunity options below.

>30mSec - Higher Immunity
Faults of over 30mS. Higher noise immunity. This is looking for a fault of over 30mS duration. Has better noise rejection than the options above.

>50mSec - Higher Immunity
Faults of over 50mS. Higher noise immunity. This is looking for a fault of over 50mS duration. Has better noise rejection than the options above and is for detecting longer.

The other buttons are as follows:

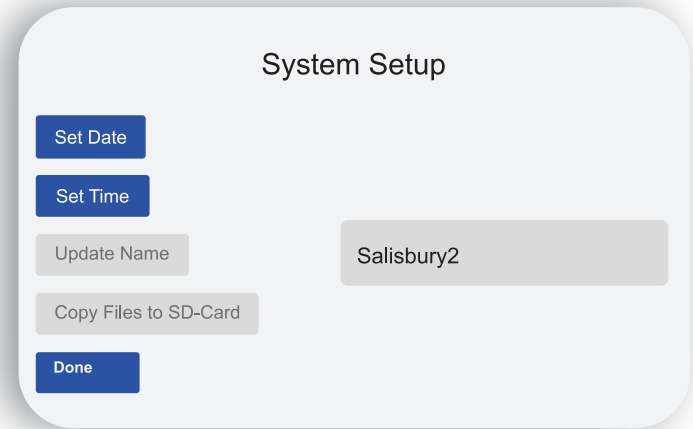
Advanced Mode
As well as the “Allow Pairing” switch (that automatically turns off when you leave the screen) there is an “Advanced Mode” switch. This adds the ability to assign a name to a specific test which gets added to the event log. Also there is the ability to capture and view the waveforms measured by each of the sensors. This is useful to determine the optimum Measurement Mode.

Measurement Mode
The optimum setting for this depends how long fault current is sustained in the cable. The default setting of “Short” is suitable for most faults, but where a rezap holds fault currents for multiple cycles, the engineer might find that one of the other settings gives lower noise hence more useful readings.

Forget Stale Sensors
Where a sensor is no longer used with a particular LV-FPI set (e.g. if it has been paired with and permanently assigned to another system) then the line allocated to it on the main screen can be deleted by pressing the “Forget Stale Sensors” button. This will remove all sensors that are not currently turned on and communicating with the concentrator.

Rename Sensors
This reassigns the numbers 1 – 6 (or however many sensors there are) to the sensors that are currently communicating, in case one or more have been removed and released by “Forget Stale Sensors”.

System Setup
This brings up another dialog box for tasks that are related to the entire system, rather than management of the Sensors.

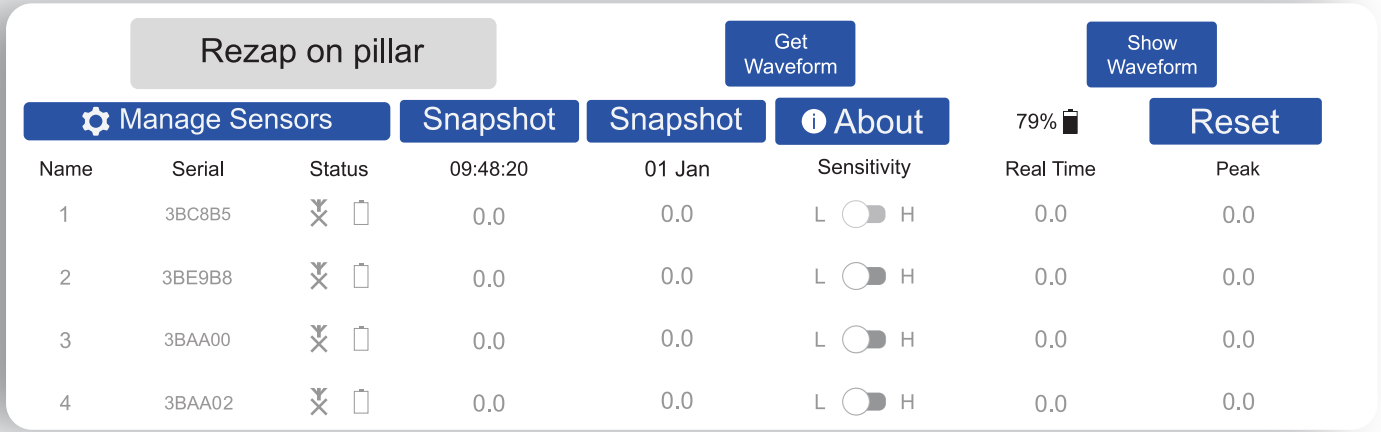


Set Date / Set Time
If the battery in the concentrator has been allowed to discharge completely, it is possible that the clock inside it has stopped or forgotten the current date and time. As the tablet is “locked down” the standard settings menus may not be accessible so the clock can be corrected here. Technical detail: Recent Android Operating systems have made it impossible to alter the system time except by way of the standard settings menu, so what this feature does is store an offset from the system time, whatever that might be.

Update Name
It is possible to copy log files of all activity to a micro-SD card, accessible through the screw panel in the case. To help you identify which LV-FPI system was used to take these measurements, it is possible to assign a name to the system. This may be edited in the text-box to the right of this button; changes can be accepted by pressing the “Update Name” button. It will only be enabled when you have made changes to the name

Copy Files to SD-Card
This gets enabled when a micro-SD card is inserted into the slot. All the files are copied to a directory E:\Android\data\com.gleevaughan.lv_fpi\files\<name of device>\ (assuming E: is the drive when you insert the card into your computer). If files are imported into a spreadsheet, then waveforms may be plotted.

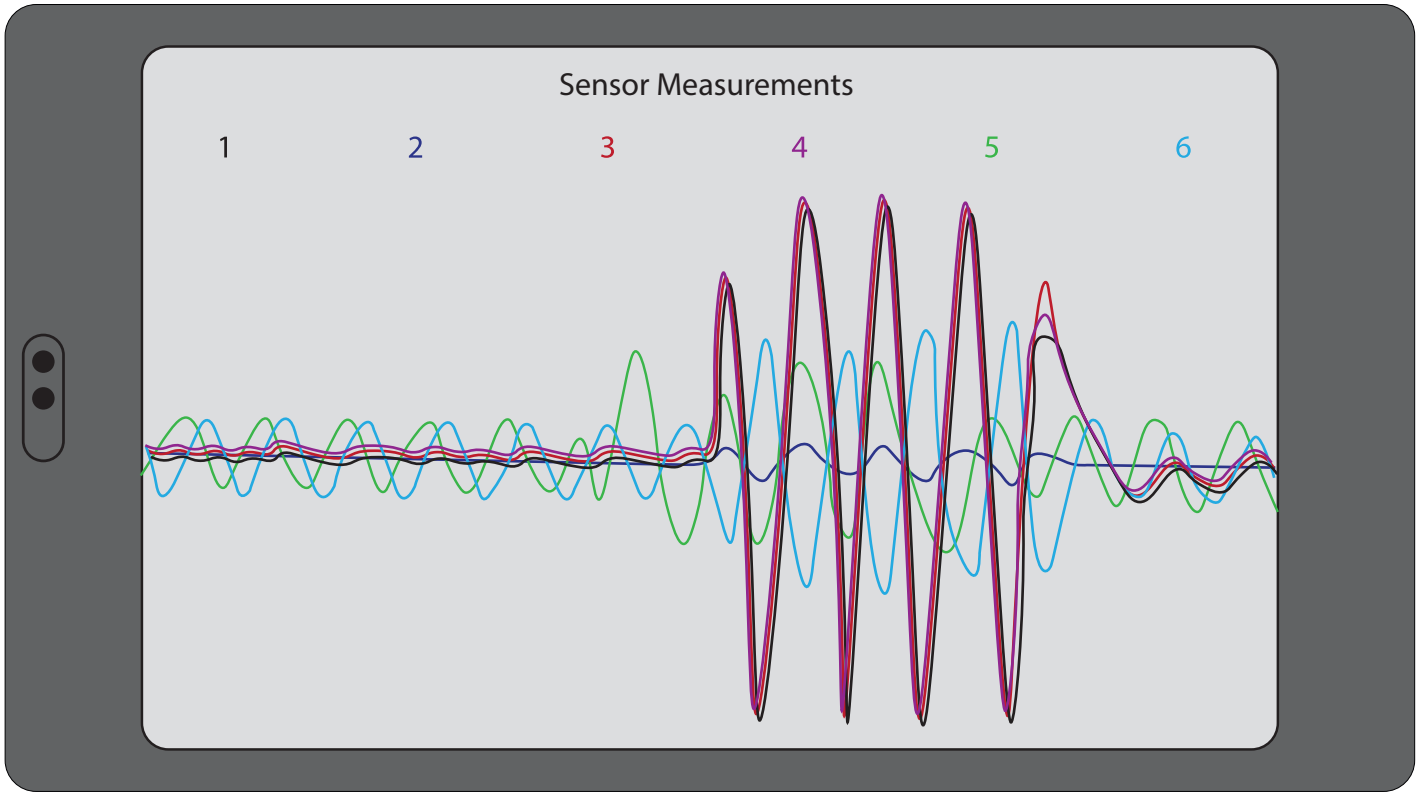
Main Screen when in Advanced Mode




The top line only shows when “Advanced Mode” is enabled in the Manage Sensors dialog. There is a text box on the left (currently showing the text “Rezap on pillar”) where the engineer may note the test setup to help remember and identify the process of locating the fault. This gets entered in the log. To edit this field tap in the box and the on-screen keyboard should appear.

Get Waveform requests all sensors to send the waveform of the most-recent peak. The log will show “Waveform request pending”, then “Waveform requested” after which readings will come back from the sensors. Once all sensors have sent their waveforms, the engineer may view the fault transient seen by the sensors by pressing “Show Waveform”.

Wave from screen when in advanced mode




### 3.5 TROUBLESHOOTING

Although the LV-FPI App should automatically launch when the switch is moved to the Operating position, it is possible that the App permissions might get lost. In that case the tablet will present a dialog box like that shown in Figure 6. You should select the “Always Open LV_FPI when USB UART is connected” then press “OK”.

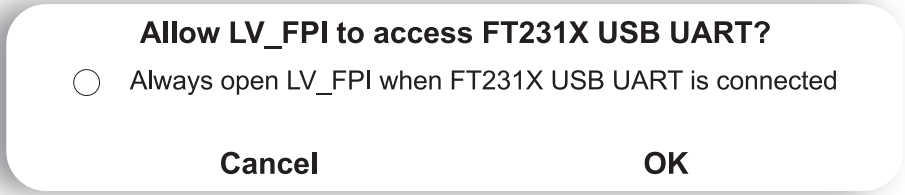



Figure 6: App permissions

Note that if the App reports “LoRa Radio Not Running” it means that radio circuit is not seen by the Android's USB interface, shown in Figure 7. If this stays up for more than a second, first ensure that the charger is disconnected or turned off. Then switch the toggle switch on the side of the Concentrator to select Operating mode. (This is because an Android tablet won't notice the change from charging-mode to operating-mode while power is being fed from the charger.)

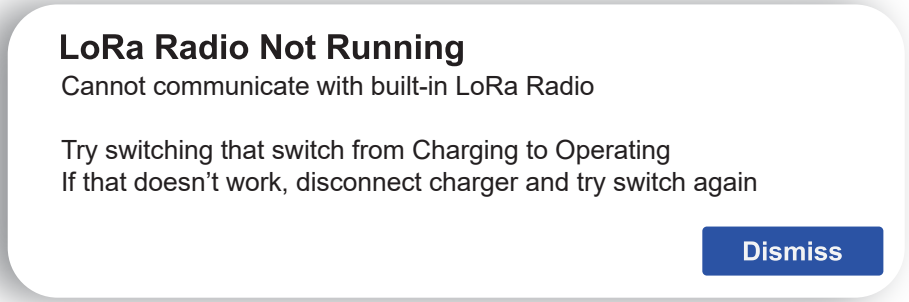



Figure 7: Radio not running

## 4.0 POWER SUPPLY

Sensors are powered by a block of 4 “AA” batteries (also known as LR6). To change batteries, undo the four corner screws of the case. When reassembling the case, it is important that the rear of the case is oriented so batteries are kept away from the coil used to measure current in the cable. This is shown in Figure 8. Note: Remember to refit the foam insert.

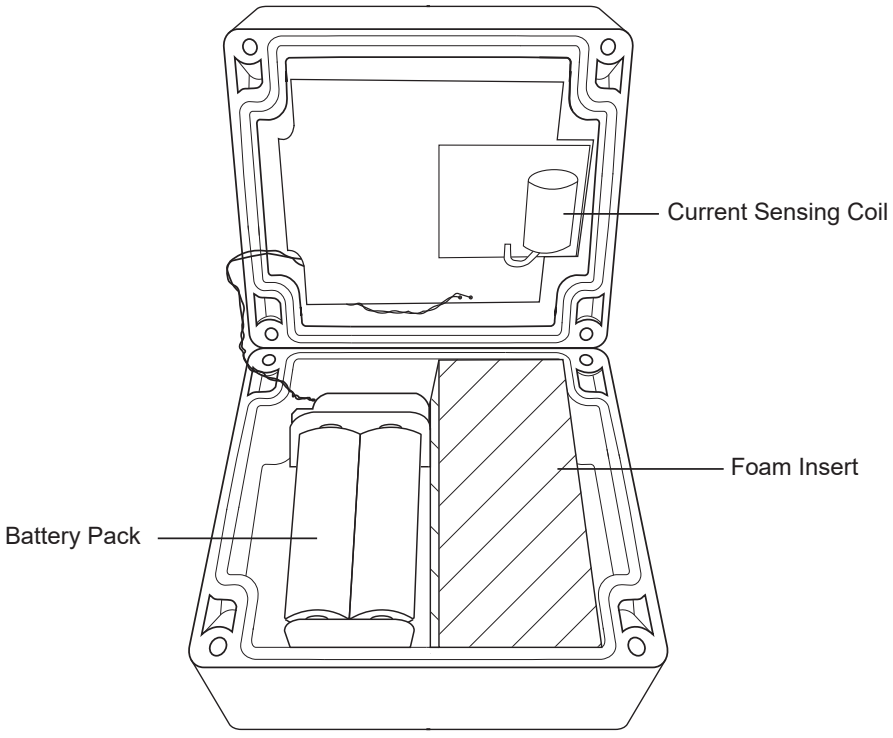



Figure 8: Changing batteries on Sensor Unit

## 5.0 SPECIFICATION

### SENSOR

Dimensions: 120 × 92 × 56mm with external LoRa antenna 208mm long.

Power Source: 4 × 1.5V AA Standard Alkaline Batteries. Battery status shown on display and at Concentrator. Expected battery life 100 hours.

Display: 96 × 16 pixel white OLED display, active area 21 × 3.5 mm. Automatic turn-off of display after five minutes; can be turned back on by pressing any button.

Enclosure: Polycarbonate – IP65

### CONCENTRATOR

Dimensions: 250 × 144 × 25 mm with external LoRa antenna 208 mm long.

Power Source: Internal LiPo rechargeable battery in tablet computer. 5.0 Volts charging voltage. Expected battery life five hours.

Enclosure: HIPS – IP44

Specification subject to change without notice.

VERSION 1.1

RELEASE 21.02.24