Tree Inspection Kit (TIK)

Acoustic measurement system of the Modulus of Elasticity (MOE) in trees, logs and boards

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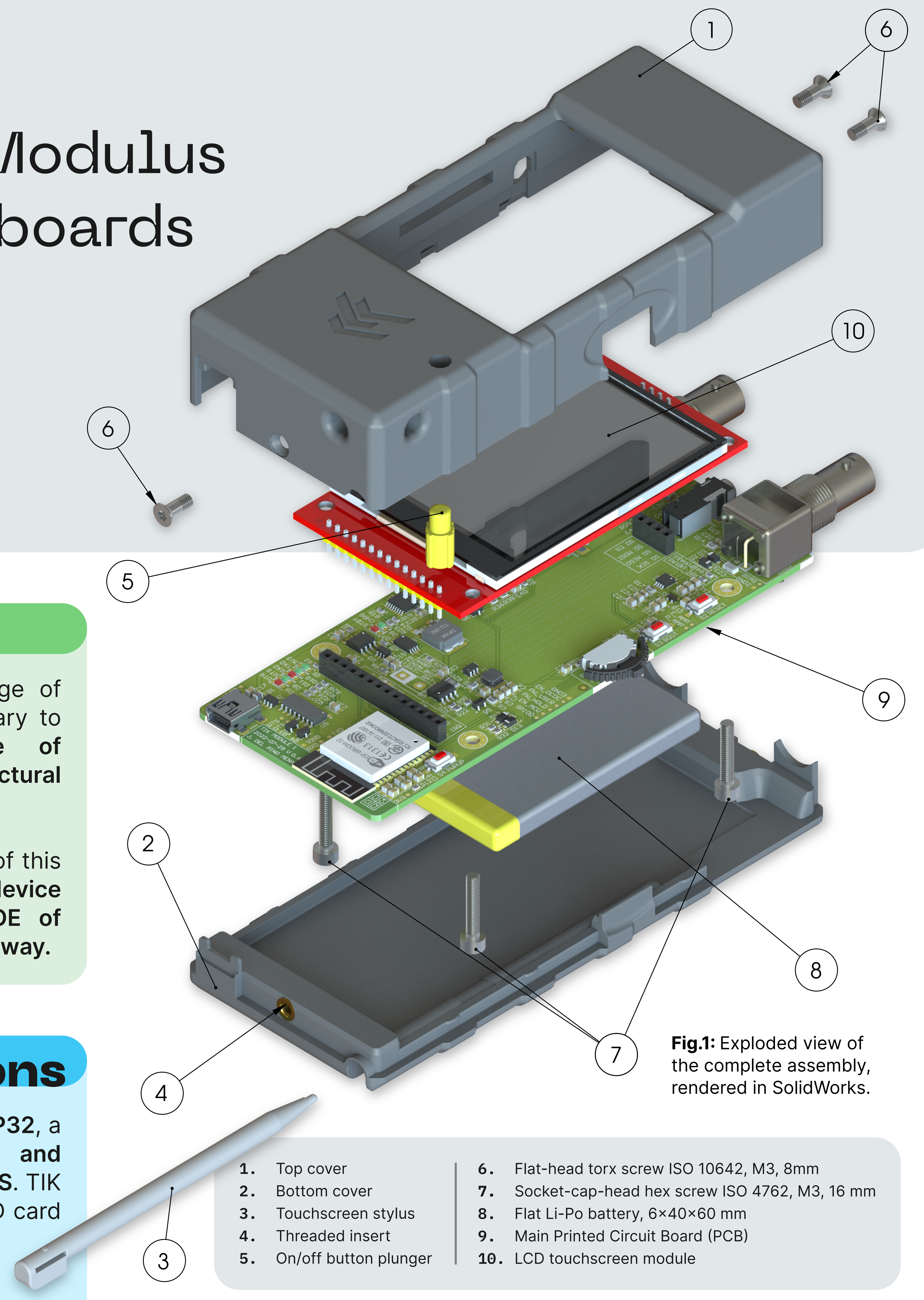

Fig.1: Exploded view of the complete assembly, rendered in SolidWorks.

1.	Top cover	6.	Flat-head torx screw ISO 10642, M3, 8mm
2.	Bottom cover	7.	Socket-cap-head hex screw ISO 4762, M3, 16 mm
3.	Touchscreen stylus	8.	Flat Li-Po battery, 6×40×60 mm
4.	Threaded insert	9.	Main Printed Circuit Board (PCB)
5.	On/off button plunger	10.	LCD touchscreen module

Motivation and Objectives

Granada has one of the worst pollution levels in Spain, just behind Madrid and Barcelona.

Contradictorily, poplar forestry in Granada has suffered a significant setback over the last two decades. **Poplar trees have great environmental benefits** including CO_2 absorption.

Now that innovative **wood composites and manufacturing processes** are being developed by research groups at the UGR, in addition to the European legislation, which promotes a **more sustainable construction and more efficient buildings**, an opportunity arises for this timber resource.

In order to take advantage of this resource it is necessary to **develop tools capable of characterising the structural properties of wood**.

This is the main objective of this project: **to create a device which measures the MOE of wood in a non-destructive way.**

Measurement method

The velocity of an acoustic wave inside a material is related to its MOE. On thin and elongated shapes the longitudinal wave can be considered to propagate as a flat wavefront. To estimate the wave velocity we use the **Time-of-Flight (ToF)** method and the **Akaike Information Criterion (AIC).**

1 Time of Flight

Two **piezoelectric probes** are **nailed in the trunk** and spaced a known distance. Then, one of them is tapped with a hammer and **waves are recorded on both probes** *(see Fig.2)*.

The propagation time is the difference between the instant *emitter* and *receiver* signals start.

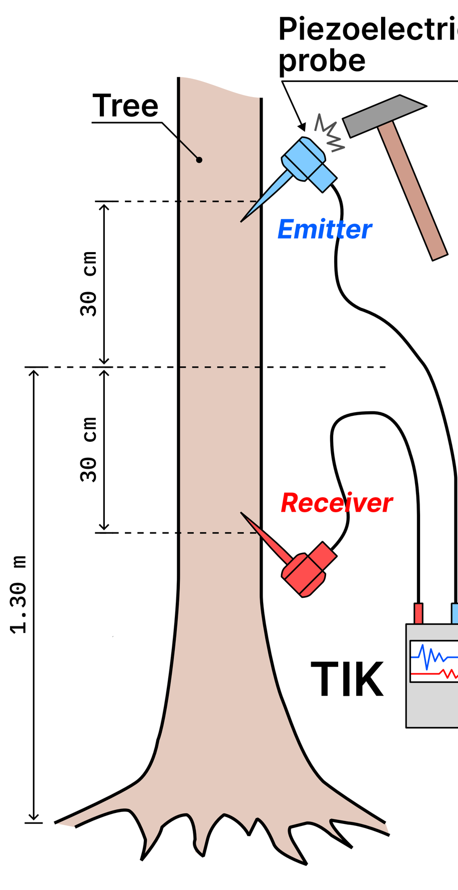

Fig.2: measurement procedure in a tree

2 Signals

Emitter and receiver signals are very different *(see Fig.3)*. The emitter has an amplitude of tens of volts and starts with a strong flank, whereas the receiver has an amplitude of hundreds of millivolts and starts gently.

3 Akaike I. C.

Akaike Information Criterion is a post-processing algorithm which **finds the starting point of a transient signal** *(Fig.4)*.

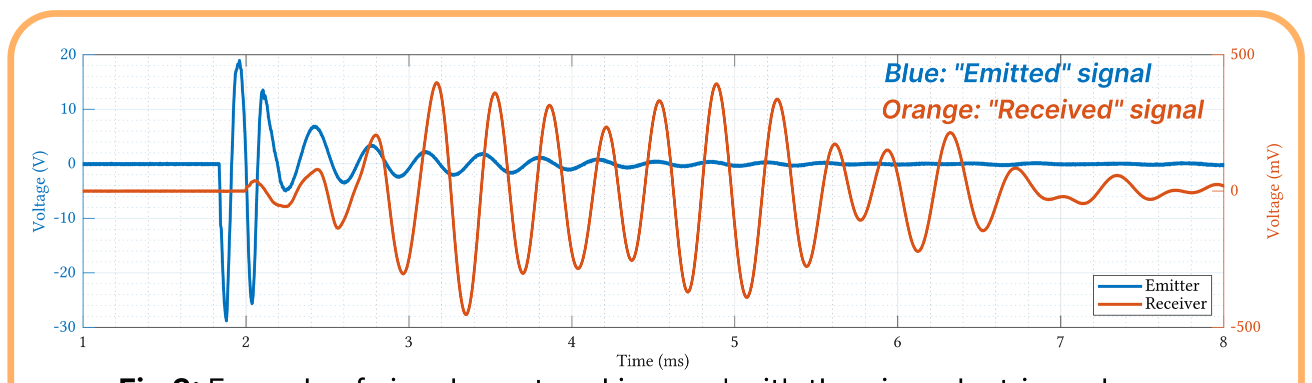

Fig.3: Example of signals captured in wood with the piezoelectric probes.

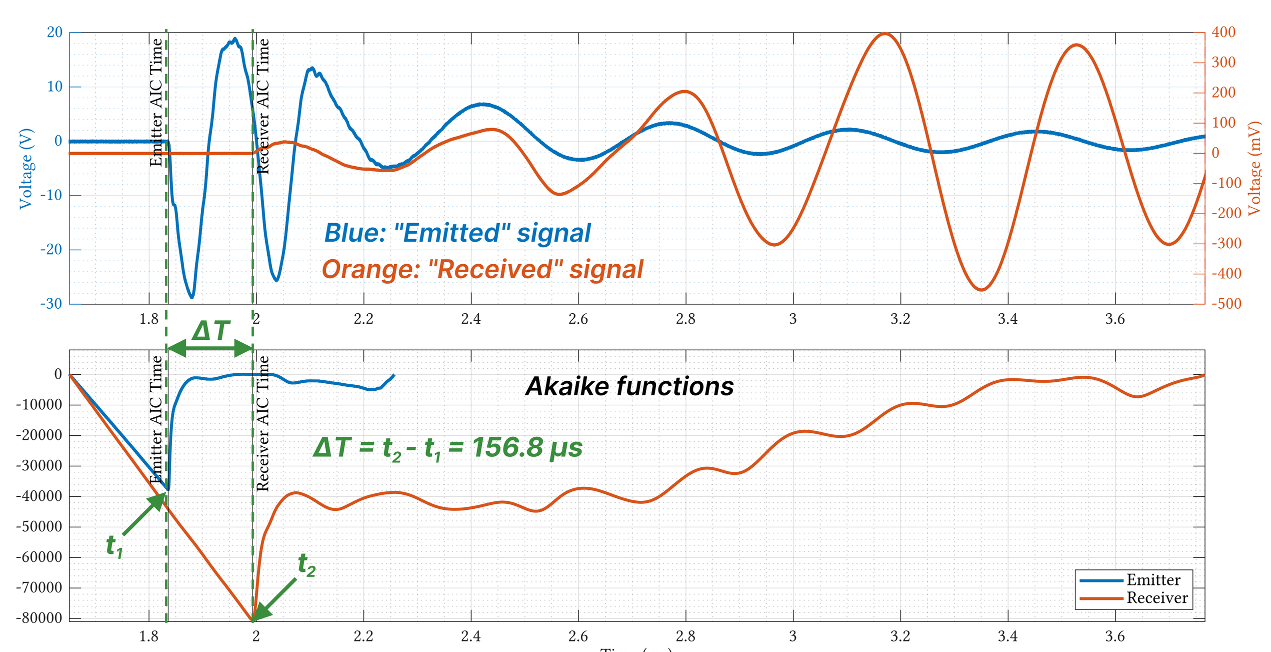

Fig.4: Detail view of the start of signals, and the result of AIC processing. In the "Akaike functions", the minimum marks the instant where the signal starts.

Specifications

The TIK prototype has an **ESP32**, a dual-core SoC with **Wi-Fi and Bluetooth**, and runs **FreeRTOS**. TIK has a **LCD touchscreen**, a SD card slot, and a Mini-USB for charging and programming.
The prototype has **between 4 and 11 hours of battery life**.
An ADC captures signals coming from the piezoelectric sensors.
A load cell can be connected in order to weigh boards and logs so their density can be estimated.
Everything is integrated on a PCB created in Altium. The housing was designed in SolidWorks.

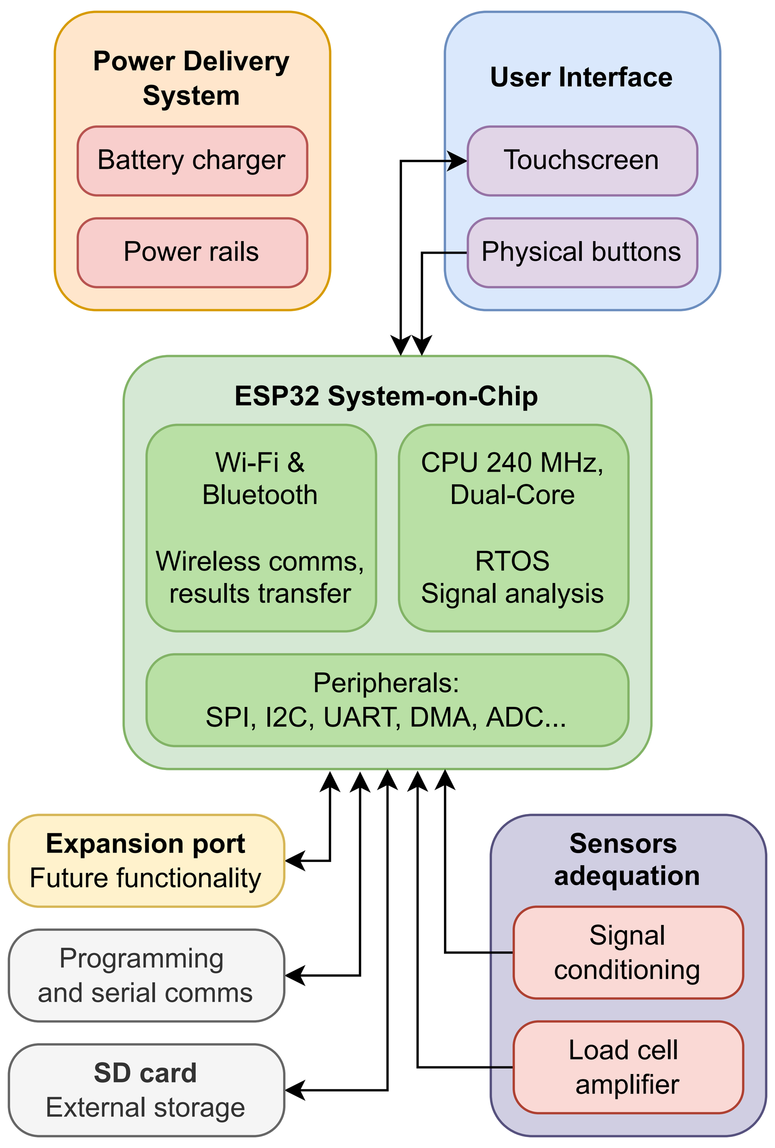

Fig.5: High-level block diagram of the electronics architecture.

Fabrication

A design was synthesised that **followed our own guidelines,** the PCB manufacturer **desing rules**, and **in-force regulations** (e.g.: RoHS, CE).
Both the PCB and its stencil were ordered. The PCB was assembled in the GranaSat laboratory. The housing was 3D-printed in Bibliomaker.
One unit has a manufacturing cost of 129€.

Fig.6: Prototype unit completely assembled and switched on.

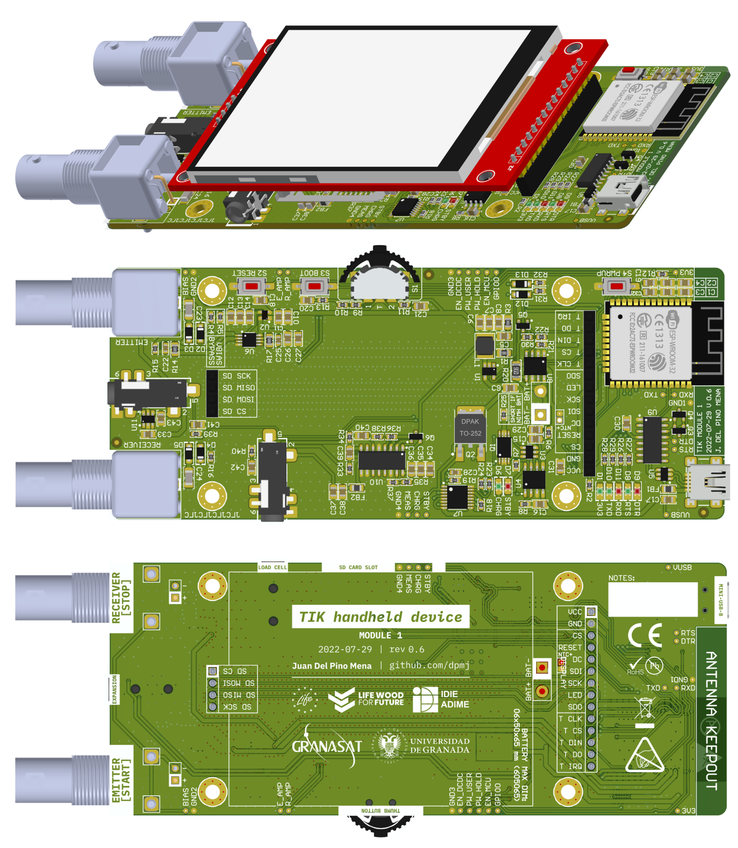

Fig.7: Some PCB renderings in Altium Designer.

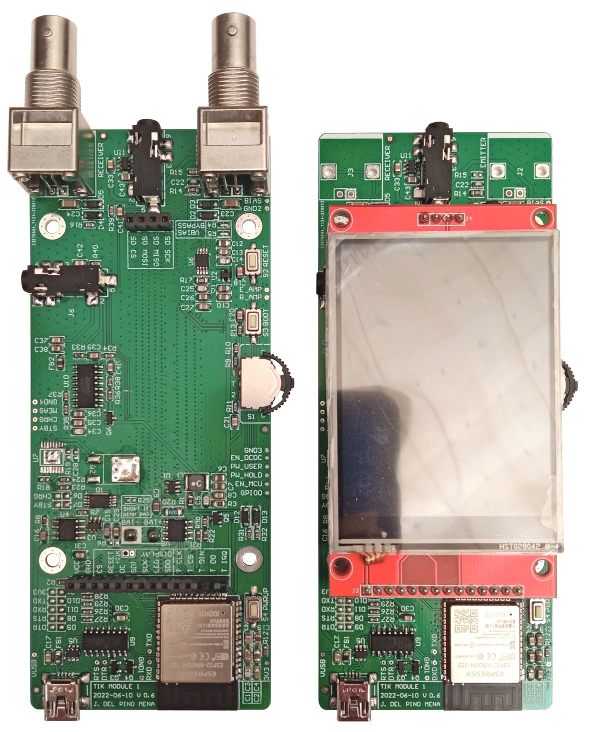

Fig.8: Two PCBs populated and soldered.

Conclusions

The project has a considerable scope. This first iteration concludes with the **fabrication of a TIK prototype,** which serves as a **basis for further development.** This milestone has meant developing a product with **electronic and mechanical co-design**.

As a side outcome of this project, signals and piezo sensors have been characterised, and the AIC post-processing algorithm has been evaluated. Other parallel milestones have been achieved, such as the handling of professional CAD & EDA software and the development of libraries for handling electronic instrumentation.

References

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[2] X. Wang, *"Acoustic measurements on trees and logs: A review and analysis,"* Wood Science and Technology, vol. 47, p. 965–975, 2013.

[3] X. Li, X. Shang, A. Morales-Esteban, and Z. Wang, *"Identifying P-phase arrival of weak events: The Akaike Information Criterion picking application based on the Empirical Mode Decomposition,"* Computers & Geosciences, vol. 100, pp. 57–66, 2016.