# Luna Advanced Sensing and Control Platform

## 1. System Architecture

Currently we have multiple reference designs and circuits that we need to combine into a single PCB.

The PCB will include the following primary subsystems:

## Analog Sensing:

* AD5940 Sensing Electronics (with emphasis on isolation and precision) **– there should be a dev board or reference design that can be used for this.**
* Enhanced Analog Front End (AFE) for Electrochemical (CA/EIS) measurements -

## Heater Control: - We need a DC/DC converter to provide current to a heater circuit

* High-precision heater drive circuit (DC/DC converter) supporting both constant current (CC) and constant voltage (CV) modes
* The DC/DC converter will be controlled with the NXP processor, it will need to read the voltage drop across a thermistor with an ADC pin. **For this we will use the sensing circuit from the WinLogic project as I have tested it and verified that it works, I will provide the circuitry**.

## Wireless Communications: - Would be nice to have this included in the board, but could sit in a carrier board

* Options include LoRaWAN and cellular (LTE variants: NB-IOT, LTE-M)

## Other Communication Interfaces:

* There will be some additional GPIOs on the NXP processor that can be used for I²C, SPI, UART, RS-485, and CAN/FD bus **- Connect the unused pins to a pin header but try to group the pins by interface**

## Subsystems: - Combine everything in this list into the board

* Main controller: NXP i.MX RT1176
  + There is a 3rd party module that might be useful for a reference design: <https://www.tq-group.com/en/products/tq-embedded/arm-architecture/tqma117xl/>
  + If the TQ Group files cannot be accessed, there is a reference design for the NXP i.MX RT1176 evaluation board: <https://www.nxp.com/design/design-center/development-boards-and-designs/i-mx-evaluation-and-development-boards/i-mx-rt1170-evaluation-kit:MIMXRT1170-EVKB>
* There is a set of external sensors on a small PCB (humidity, temperature, pressure), this external board will need to connect to the Luna PCB possibly via an FPC
* We will need an on-board temperature sensor, such as a Bosch environmental sensor
* We will include the CORAL TPU for machine learning tasks, I have provided the Coral Dev Board reference design to help with this
* Crypto chip/secure element (SEO50)

## Power Management: - Need to provide analog supply and separate digital supply

* PMIC power control (e.g., MPF5020 or a similar device)

Note: The design must enable selective integration so that optional subsystems (such as the Coral TPU or specific wireless modules) can be removed or left unpopulated without compromising the overall system integrity.

## 3. Detailed Requirements

**3.1. AD5940 Sensing Electronics and Analog Front End (AFE)**

**Objective:** Enhance the precision and noise performance of the analog sensing chain to meet or exceed the performance benchmarks (e.g., those seen in Palmsense hardware).

## Key Requirements:

* Testability and Debugging
  + Provide sufficient test points on the PCB for in-circuit verification and debugging.
* Signal Integrity & Conditioning:
  + Implement low-pass filtering and shielding where necessary to minimize noise.
  + Use an ultra‑low-noise, high‑stability voltage reference (e.g., ADR4520) for analog references to maintain baseline stability.
  + Consider external precision ADC options (e.g., AD7768) if the internal ADC performance of the AD5940 is insufficient.
* Bias and Excitation:
  + Optimize electrode biasing with fine-tuning options.
  + Evaluate the use of a dedicated sine wave generator (such as an external DDS like AD9833) to improve the excitation signal for EIS measurements.
* Layout & Power:
  + Use multi‑layer PCB design with dedicated ground planes for the analog section.
  + Separate analog and digital sections to reduce interference.
  + Prefer low‑noise LDO regulators or isolated DC/DC converters for powering the analog front end.
* Isolation:
  + Implement isolation techniques (digital isolators, optocouplers) to prevent ground loops and noise coupling from digital circuits into the analog section.

## 3.2. Heater Control Circuit

This is a critical subsystem requiring a high‑precision design with robust isolation. The following requirements must be met:

## 3.2.1. Functionality

* Drive Modes:
  + Support both constant current (CC) and constant voltage (CV) drive modes.
* Heater Resistance Range:
  + Operate with heater resistances from 0.2 Ω to 10 Ω (and potentially higher).
* Precision:
  + Provide high resolution and fine control over current and voltage to ensure accurate heater operation.

## 3.2.2. Sensing and Feedback

* Voltage Sensing:
  + Incorporate a precise voltage measurement at the heater terminals.
* Current Sensing:
  + Use a high-precision current sense amplifier (either low‑side or high‑side) for accurate current measurement.
* Feedback Loop:
  + Feed the sensed voltage and current data back to the NXP i.MX RT1176 MCU via an isolated interface.

## 3.2.3. Isolation

* Electrical Isolation:
  + Fully isolate the heater control circuit from the rest of the system.
  + Use optocouplers or digital isolators for data communication where applicable (such as from the ADC back to the NXP processor).
  + Deploy isolated DC/DC converters to maintain separate power domains where applicable.
* Feedback Isolation:
  + Isolate the sensing signals (voltage and current) using appropriate isolation ICs to prevent noise or ground loop issues.

## 3.2.4. Power Supply

* Heater Supply Requirements:
  + Design a power supply capable of handling a wide range of voltage requirements.
  + Consider the use of programmable DC/DC converters or precision linear regulators.
* Driver Capability:
  + Ensure the heater driver is robust enough to handle both low-resistance (high-current) and high-resistance (low-current) scenarios safely.

## 3.2.5. Protection

* Overcurrent/Overvoltage:
  + Include protection circuits to guard against potential heater faults, such as short circuits or excessive current draw.
* Thermal Monitoring:
  + Optionally integrate temperature sensors to monitor the heater temperature for additional safety.

**3.2.6. Control and Communication**

* **Digital Interface:**
  + Provide a digital communication interface (I²C, SPI, or UART) for the MCU to control and monitor the driver for the heater circuit and any external sensing element (two-wire thermistor) for temperature sensing.
* **Isolated Data Lines:**
  + Ensure that communication lines to the MCU are isolated to eliminate noise and ground loop issues.

**3.2.7. PCB Layout Considerations**

* **Noise Reduction:**
  + Optimize the layout to minimize noise and crosstalk.
  + Careful placement of current and voltage sensing components is critical to maintain measurement accuracy.
* **Thermal Management:**
  + Consider the thermal impact of the heater control circuitry on adjacent sensitive components.
  + Use dedicated copper pours or thermal vias as necessary.

**3.2.8. Suggested Components**

* **Power Modules:**
  + Isolated DC/DC converter with tight regulation and adequate power handling.
* **Sensing Components:**
  + High-precision current sense amplifier (low‑drift, appropriate range).
  + Precision voltage references and ADCs/DACs as required.
* **Isolation Devices:**
  + Digital isolators or optocouplers for both data and sensing feedback isolation.