# LoRa ADC Sensor Node Project

A high-resolution wireless sensing platform built on the STM32WL SoC, integrating LoRa communication, a precision analog front end, and environmental/motion sensors. Optimized for low-power, long-range telemetry, and accurate analog signal acquisition.

## 🧠 System Overview

MCU: STM32WL (ARM Cortex-M4 + LoRa transceiver)  
Comms: LoRaWAN / P2P LoRa for ultra-low-power, long-range data transfer  
Function: Real-time analog signal acquisition + edge processing

## 📈 Analog Front-End (AFE)

Input: Analog via SMA, sub-25 kHz sensors (e.g., piezo, geophone, mic, current probe)  
Architecture:  
 • Pseudo-differential input, centered on 1.65 V bias  
 • MCP6001T op-amp in Sallen-Key Butterworth LPF (~25 kHz cutoff)  
 • Signal swing: 0–3.3 V (no rail-to-rail required)  
ADC:  
 • ADC141S626 14-bit SAR, SPI interface  
 • External precision reference ensures consistent performance

## 🌡️ Sensor Suite

BME280: Temperature, humidity, pressure  
MPU-6050: 3-axis accelerometer + gyroscope

## 🔋 Power Design

• LDOs for low-noise analog rails  
• Buck converters for digital supply efficiency  
• Isolated analog/digital domains with careful grounding

## 📡 RF Front-End

• Impedance-matched + filtered layout  
• Optimized for LoRa range + ETSI/FCC compliance

## 🛡️ EMC & RF Design Considerations

• Layer stackup designed for controlled impedance and signal integrity:  
 - Top Layer: High-speed signal & RF traces  
 - Inner Layer 1: Solid ground plane  
 - Inner Layer 2: Power plane (split analog/digital rails with stitching caps)  
 - Bottom Layer: Low-speed signals and LoRa antenna feed  
  
• RF considerations:  
 - 50Ω trace impedance matched to SMA and LoRa antenna  
 - Minimized stub length and via transitions  
 - Grounded copper pour and RF shielding around sensitive analog areas  
  
• EMC best practices:  
 - TVS diodes on SMA and sensor inputs  
 - Proper decoupling (0.1µF + bulk) close to every IC  
 - Ferrite beads separating analog/digital domains  
 - Return current paths carefully maintained  
 - ESD protection on exposed interfaces