

Testing

Test organization, the Unity testing framework usage, coverage per suite, manual hardware testing checklists and a debugging/troubleshooting guide. Reminder: the sensor board code was only partially tested; unit tests cover the pure-logic parts of the drivers, and end to end hardware validation was not completed by the 2025-2026 team.

Test Organization

Suite	Location
test_sensor_basics	test/sensor_board/test_sensor_basics/test_sensor_basics.c
test_ph_sensor	test/sensor_board/test_ph_sensor/test_ph_sensor.c
test_imu_sensor	test/sensor_board/test_imu_sensor/test_imu_sensor.c

Test Framework

- **Framework:** Unity (open source C testing framework)
- **Build system:** PlatformIO (env:sensor_board, test_filter = sensor_board/*)
- **Test type:** driver logic tests exercising the data structures and math directly; the hardware access paths (ADC, HX711 GPIO, EXTI) are not mocked and not covered

Building and Running Tests

```
# All sensor board tests
pio test -e sensor_board

# One suite
pio test -e sensor_board -f test_ph_sensor

# Verbose output
pio test -e sensor_board -f test_sensor_basics -v
```

Coverage Per Suite

test_sensor_basics

- Accelerometer boundary values: ± 160.0 accepted, ± 160.1 rejected
- Multi-axis validation: one bad axis fails `validate_imu_data()`
- Temperature and pressure conversion tests exist but are commented out together with their implementations

test_ph_sensor

- Initialization defaults (raw 0, voltage 0, pH 7.0, stored reference voltage)
- ADC to voltage to pH conversion with a 12-bit ADC scale
- Clamping at the extremes (ADC 0 clamps to pH 14, full scale clamps to pH 0 with the test calibration)
- Calibration changes the measurement (offset and slope applied)

test_imu_sensor

- Initialization zeroes all axes and the timestamp
- Update and read round-trip for accel/gyro/mag and timestamp
- Acceleration magnitude (3-4-12 triangle gives 13)
- Pitch and roll helpers from accelerometer data
- Range validators accept zeros and reject out-of-range values

Manual Hardware Testing Checklist

1. Flash with `pio run -e sensor_board -t upload` and open the serial monitor at 115200 baud
2. Confirm the boot banner and each "init completed" line (IMU, pH, load cells, pressure, flow, pump, Ethernet)
3. Confirm the three LEDs toggle every 5 seconds (loop heartbeat)
4. Check the per-sensor status lines: connected hardware should read OPERATING | OK, absent hardware IDLE | DISCONNECTED
5. Load cells: press on each cell and watch `raw_counts/force` change; verify tare at startup reads near zero
6. Flow and pump: with tubing wet, enabling the pump must produce flow pulses; "commanded on but no flow detected" indicates a dry/absent pump or a not-configured EXTI4 line
7. Network: set `sendUDP = true`, then capture UDP datagrams on port 1500 at 192.168.0.222 and decode with the PBEvelope schema

8. Send a SensorBoardPumpInfo command packet and verify the pump speed changes

Debugging & Troubleshooting

Issue	Cause	Solution
Sensor IDLE / DISCONNECTED	Not connected, or driver compile gated	Check wiring; for pH/pressure verify the PH_SENSOR_USE_ADC / PRESSURE_USE_ADC build flags and the CubeMX ADC config
Sensor ERROR	Communication failure	Verify HX711 wiring and timing, I2C address and pull-ups, ADC channel binding
Invalid data	Out of range values	Check calibration parameters (pH slope/offset, load cell scale/tare, pressure scale/offset)
Flow always 0	EXTI4 not enabled in CubeMX	Configure PA4 as EXTI4 rising edge and enable the EXTI4 NVIC line
Pump OPERATING / DISCONNECTED	No flow while commanded on	Pump absent, dry, or stalled; or the flow sensor is not installed/configured
No UDP packets	Transmit gate or addressing	Set sendUDP = true; check IP/MAC constants, MAC filtering, and that port 1500 is not blocked
Low heap warning	Memory leak or queue growth	Review protobuf encode/free paths and UDP queue sizes
Serial monitor silent	Wrong port or baud	Check the ST-Link COM port and 115200 baud; verify LOG_init ran

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