SENS-SOIL-NPK-V1 - Operating Instruction

1. Purpose and Principle of Operation

1.1 Purpose

`SENS-SOIL-NPK-V1` is a dual-mode LTE-M/NB-IoT telemetry module for NPK trend monitoring in field deployments.

The module is intended for periodic collection and transmission of: - nutrient channels (N, P, K) - optional associated soil chemistry metadata - optional GPS position metadata

1.2 Scope of Application

- Precision fertilization planning
- Nutrient depletion and recovery tracking
- Zone-level comparison for fertigation strategy
- Remote agronomic telemetry

1.3 General Operating Algorithm

1. The module polls connected nutrient sensing channels.
2. Readings are validated and buffered.
3. Data is transmitted by LTE-M/NB-IoT on configured contact schedule.
4. Failed transmissions are retried from buffered data.

2. Specifications

Parameter	Value / Notes
Device type	`SENS-SOIL-NPK-V1`
Connectivity	LTE-M (Cat-M1), NB-IoT (Cat-NB1/NB2)
Network transport	LTE-M/NB-IoT with fallback and retry policies
Operating temperature	-20 to +85 °C
Standby current (battery mode)	150mk
Dimensions	250 x 30 x 30 mm

Weight	183 g
Sensor profile	NPK sensing
Positioning	GPS profile supported
Service interfaces	Hall sensor trigger
Enclosure class	IP67/IP68 variant-dependent
Firmware updates	OTA supported

3. Device Elements and Connections

3.1 Main Elements

1. Integrated sensor harness (factory-connected)
2. LED indicators
3. Hall sensor zone

3.2 Field Integration Notes

- Place NPK sensing points in representative irrigation sectors.
- Keep installation depth and sensor placement consistent between campaigns.
- Use fixed sampling windows for comparable nutrient trend analysis.

4. Hall Sensor Actions

Magnet hold time	Action
1-2 s	Show last diagnostics code
2-4 s	Trigger measurement cycle
4-6 s	Trigger cloud communication
6-8 s	Trigger GPS-only cloud communication
15-20 s	Enter warehouse mode
>25 s	Reset storage and device model

Note: A hall sensor interaction also opens the BLE service window for the configured settings timeout.

5. LED Indication

Indicator	Meaning
`INFO`	State and error code patterns
`STATUS`	Cloud connection stage heartbeat

Firmware LED patterns:

LED	Pattern	Meaning
`INFO`	1 blink	Device wake-up/initialization complete
`INFO`	3 blinks (every 60 s)	Warehouse mode active
`INFO`	5 blinks [1 long + 2 shorts]	Entering warehouse mode
`INFO`	10 blinks [3 long + 1 short]	Exiting warehouse mode
`STATUS`	1 blink heartbeat every 3 s	Initialization and SIM/APN checks
`STATUS`	2 blinks heartbeat every 3 s	Requesting full functionality (`CFUN=1`)
`STATUS`	3 blinks heartbeat every 3 s	Network registration
`STATUS`	4 blinks [1 long + 1 short] heartbeat every 3 s	DNS resolution
`STATUS`	5 blinks [1 long + 2 shorts] heartbeat every 3 s	MQTT open
`STATUS`	6 blinks [2 long + 0 shorts] heartbeat every 3 s	MQTT connect
`STATUS`	7 blinks [2 long + 1 short] heartbeat every 3 s	MQTT subscribe

`STATUS`	8 blinks [2 long + 2 shorts] heartbeat every 3 s	Data publish
`STATUS`	9 blinks [3 long + 0 shorts] heartbeat every 3 s	GNSS-only flow

Blink encoding for values above 3 uses mixed long and short blinks:

- short blink: 20 ms ON, 100 ms OFF
- long blink: 100 ms ON, 300 ms OFF

6. Installation and Commissioning

6.1 Installation Sequence

1. Confirm selected module SKU and planned installation point.
2. Follow the RS-485 soil sensor installation procedure from the hardware repository for placement depth and field handling.
3. Install the enclosure and secure it to a stick/pole using the supplied zip ties through top and bottom slots.
4. Keep the factory-connected sensor harness intact and verify only LED/Hall access is needed in routine deployment.
5. Trigger measurement and communication using the Hall sensor.
6. Confirm nutrient data in backend dashboard.

6.2 Commissioning Recommendations

- Capture baseline nutrient profile after stabilization.
- Correlate N:P:K trends with fertigation interventions.
- Trigger agronomic review on persistent divergence.

7. Nutrient Interpretation and Operational Actions

7.1 Baseline and Depletion Tracking Framework

Use an initial baseline period and compare each zone against its own trend and peer zones: Without the Sensorius platform pipeline, exported readings are raw telemetry values and are not automatically normalized.

Parameter	Starting guidance	Operational trigger

Baseline window	10-21 days after installation or major soil intervention	Extend baseline if weather/irrigation is unstable
Nitrogen (N) depletion rate	Track daily/weekly slope per zone	Escalate when slope exceeds expected crop uptake profile
Phosphorus (P) drift	Monitor low-mobility trend over multi-week window	Investigate root-zone availability when decline is persistent
Potassium (K) variance	Compare variance by zone and growth phase	Trigger inspection when one zone diverges from peer cluster
Sampling cadence	1-4 samples/day (phase dependent)	Increase during fertigation changes or stress periods

7.2 Variable-Rate Intervention Workflow

1. Rank zones by nutrient deficit severity and depletion velocity.
2. Assign intervention tier:
   - Tier 1: monitor only (within control band)
   - Tier 2: moderate variable-rate correction
   - Tier 3: immediate corrective fertigation + field inspection
3. Apply rate changes in bounded increments (for example +/- 10-20% per correction cycle).
4. Validate post-intervention response within 24-72 hours.
5. Roll back or escalate based on response quality and operational constraints.

7.3 Nutrient Optimization KPIs

- N:P:K balance compliance by zone (% samples in target ratio band)
- Mean time to nutrient recovery after intervention
- Fertigation efficiency (nutrient correction per applied unit input)
- Frequency of repeated interventions per zone
- Zone ranking stability across growth stages

8. Nutrient-Management Use Cases

Use case	Decision pattern	Operational outcome

Weekly fertigation planning	Use zone depletion slopes to pre-plan nutrient mix and timing	More consistent dosing and reduced reactive corrections
In-season depletion tracking	Compare weekly NPK trend against expected crop uptake curve	Earlier detection of underfeeding and lower yield risk
Variable-rate zone correction	Apply tiered nutrient-rate changes by deficit severity	Lower input waste and better zone-to-zone uniformity
Post-event recovery (rain/heat stress)	Reassess NPK drift after weather anomaly and rebalance feeds	Faster recovery to target nutrient profile
Program benchmarking across fields	Compare KPI performance between fields/seasons	Data-backed refinement of fertigation strategy

9. Operation and Maintenance

- Inspect enclosure and cable sealing on service cycle.
- Review communication and battery trends monthly.
- Maintain calibration and maintenance logs.
- Apply OTA updates using approved release workflow.