SENS-FLOW-CTRL-V1 - Operating Instruction

1. Purpose and Principle of Operation

1.1 Purpose

`SENS-FLOW-CTRL-V1` is a dual-mode LTE-M/NB-IoT field controller for irrigation/fertigation actuation and digital input telemetry.

Primary control and telemetry interfaces: - 12V output with reversible polarity for external actuator control - digital inputs `IN1` and `IN2` for pulse/state monitoring

1.2 Scope of Application

- Irrigation valve control
- Fertigation sequence automation
- Leak/anomaly monitoring using digital input events
- Remote operation of distributed flow infrastructure

1.3 General Operating Algorithm

1. Device monitors configured inputs and schedules.
2. Control actions are executed according to policy.
3. Events and measurements are buffered.
4. Data and state changes are sent through LTE-M/NB-IoT.

2. Specifications

Parameter	Value / Notes
Device type	`SENS-FLOW-CTRL-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
Control output	12V rail with reversible polarity
Digital inputs	`IN1`, `IN2`
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 cable harness (power, control, and I/O leads)
2. LED indicators
3. Hall sensor zone

3.2 Wiring and Safety Notes

- Validate actuator voltage/polarity requirements before connection.
- Confirm `IN1` / `IN2` signal type and debounce settings in configuration.
- Define fail-safe behavior for communication loss scenarios.

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 module SKU and controlled actuator profile.
2. Verify shipped lead set for this variant (power, control output, and `IN1` / `IN2`).
3. Install enclosure and route the prewired harness to actuator and field wiring.
4. Verify startup LED sequence.
5. Use the supplied zip ties through top and bottom slots to secure the unit on a stick/pole if required.
6. Test safe monitor-only mode, then enable controlled actuation after telemetry validation.

6.2 Commissioning Recommendations

- Start with conservative operation windows.
- Configure anomaly alerts for repeated starts or long runtime.
- Validate command execution feedback before unattended operation.

6.3 Baseline Configuration for Reliable Operation

Set initial values and tune after 2-4 weeks of field telemetry:

Parameter	Initial value	Adjustment signal
Max valve open time	10-30 min by zone type	Decrease when runoff/waste appears; increase when soil deficit persists
Minimum off interval between cycles	5-15 min	Increase when pressure drops or pump over-cycling appears

Input debounce (`IN1` / `IN2`)	200-500 ms	Increase when noise generates false pulses
Leak alarm threshold	2-5 consecutive abnormal pulses while valve is closed	Lower for critical zones, raise for noisy hydraulic lines
Command retry policy	1 immediate retry + alarm on second failure	Increase retry delay if actuator needs longer settle time

7. Data Interpretation and Process Actions

7.1 Core Telemetry to Track

- `cmd_exec_ok_rate` : % of successful valve/open-close commands
- `valve_runtime_s` : accumulated open duration per cycle
- `input_pulse_count` : pulses from flow or state channel during a control window
- `unexpected_pulse_events` : pulses while actuator should be closed
- `retry_count` : number of command retries per day/zone

7.2 KPI Examples for Process Optimization

- Command success rate per zone and shift
- Water delivery per open-minute (pulse efficiency)
- Leak alarm frequency per 100 operating hours
- Average response time from leak alert to valve isolation
- Overrun minutes outside approved irrigation/fertigation windows

8. Industrial Use Cases

Use case	Sensor/control signal value	Optimization outcome
Multi-zone irrigation scheduling	Runtime + pulse feedback by zone	Reduced overwatering and more stable crop stress levels
Fertigation batch execution control	Valve sequence confirmation + cycle timing	Consistent nutrient dosing and lower chemical waste
District valve sequencing for shared pumps	Coordinated open windows + minimum off intervals	Lower pump stress and reduced peak energy demand

Leak isolation in remote branches	Unexpected pulse events while closed	Faster incident response and water-loss reduction
Remote pumping window enforcement	Command logs vs approved time windows	Better compliance with utility tariffs and site policies
Seasonal retuning of water strategy	KPI drift across weeks/months	Data-driven tuning of schedules and thresholds

9. Operation and Maintenance

- Inspect wiring terminals and seals each service cycle.
- Review event and command success metrics monthly.
- Revalidate fail-safe policy after firmware changes.
- Apply OTA updates through approved workflow.