

Naple Raven-01 Architecture Technical Brief

Early Warning at the Edge of the Sewer Network

Sensor-hub chip · Tang Nano 9K prototype platform

21 October 2026

Covers the Raven-01 architecture, its temperature-corrected measurement engine, its interfaces, simulated detection performance, and its implementation on the Gowin GW1NR-9 FPGA.



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Naple Raven-01: Built for Early Warning in Failing Sewers

In many South African neighbourhoods, sewer manholes overflow without warning, and community interviews describe overflows that stay unrepaired for days to weeks. Raw sewage on the street is a public-health, environmental and cost problem at once.

The physics of a manhole shows why warning has to come early. For a chamber of plan area A_m fed at inflow Q_{in} , conservation of mass gives $A_m dh/dt = Q_{in} - Q_{out}$. Once the outlet is fully blocked, the time from an alarm level h_a to the rim H is only

$$t_w = A_m (H - h_a) / Q_{in}$$

which is 13 to 52 minutes per metre of freeboard at 1 L/s for chambers of 1.0 to 2.0 m diameter

DERIVED. Nobody can dispatch a repair crew in minutes. Useful warning must therefore come while a blockage is still **partial**, days before the manhole spills.

Enter **Naple Raven-01**, a digital sensor-hub chip that measures the water level in a manhole, learns what normal looks like at that site, and reports only when something changes. In simulation on estimated sewer values, Raven-01 warned of a developing blockage about five days before the first overflow.

This brief describes the Raven-01 architecture, its temperature-corrected measurement engine, its interfaces and its implementation on the Tang Nano 9K FPGA platform. Raven-01's event-detection engine is proprietary to Naples and is described here by what it does, not how it does it.

Naple Raven-01 Overview

Raven-01 is Naples Semiconductor's first complete chip design: a synchronous, single-clock digital sensor hub written in synthesizable SystemVerilog, verified byte for byte against an independent reference model in two simulators, and placed and routed on a Gowin GW1NR-9 FPGA with an open-source toolchain. It is Naples's reference design, built to show the full path from a real-world problem to verified logic.

Development status, 21 October 2026. The design is complete and verified in simulation. FPGA implementation has been completed in design tools only; it has not yet been run on a board, and no Raven-01 silicon exists. Performance figures in this brief come from simulation on estimated sewer values, not from field measurements.

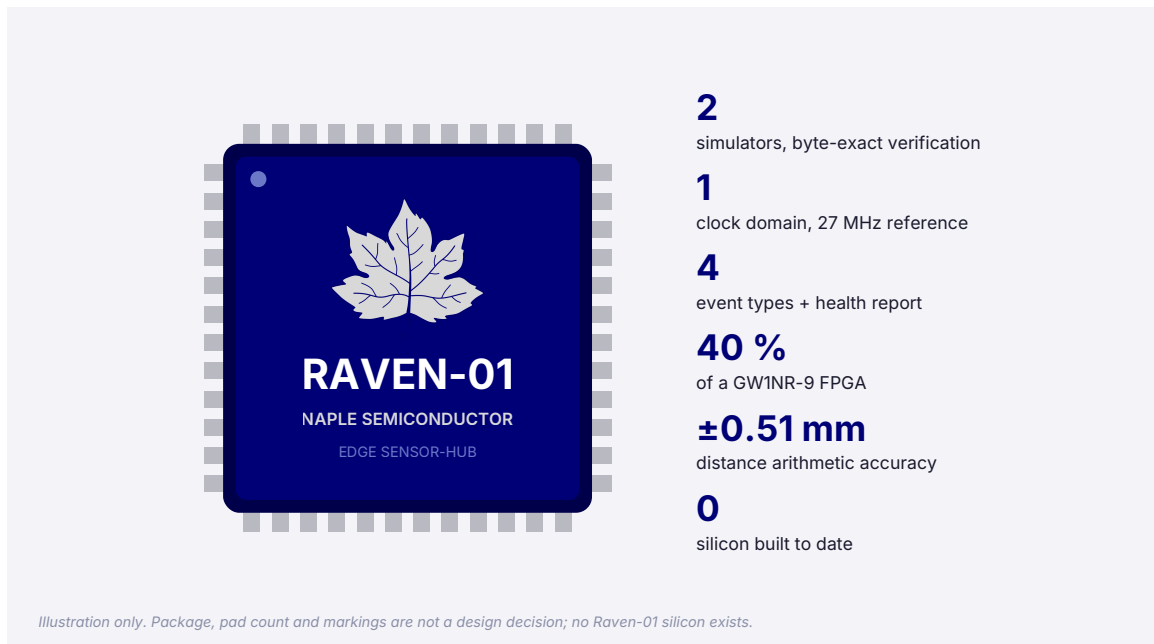


Figure 1. Naples Raven-01 Sensor-Hub Chip (design representation)

Table 1. Raven-01 Development Status

Area	Status	Basis
Digital design (RTL)	Complete	Full regression passes in Verilator and Icarus
Distance arithmetic	Complete	Exhaustive check, 64.4 million cases
FPGA place and route	Complete in tools	Timing met at 27 MHz
Bench test on the FPGA board	Next	Board and sensors to be obtained
Field trial	Not started	Needs bench test and site permission
Silicon	Planned	Shared open-process run; not yet scheduled

Raven-01 Architectural Innovations

Raven-01 puts a complete measure-and-decide chain into one small, deterministic piece of logic. Six features carry the design.

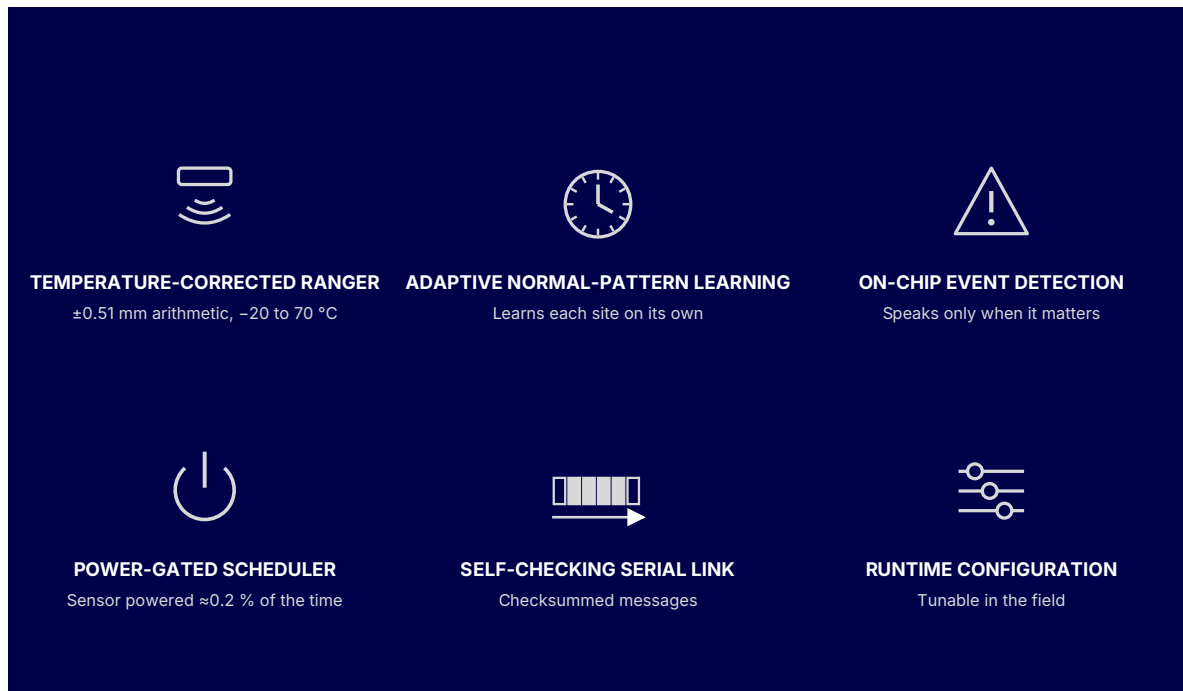


Figure 2. Raven-01 Architecture's Technological Features

A New Class of Sensor-Hub Chip

Most sensor nodes stream raw readings to a server and leave the thinking to software. Raven-01 makes the decision at the edge: the chip learns its own manhole's behaviour and speaks only when something changes, plus a periodic health report that proves it is alive. A quiet radio is what makes a battery-powered node under a manhole lid practical.

The design runs in a single clock domain with a synchronous reset. Every physical quantity carries its unit in its signal name, and every module passes Verilator lint with zero warnings.

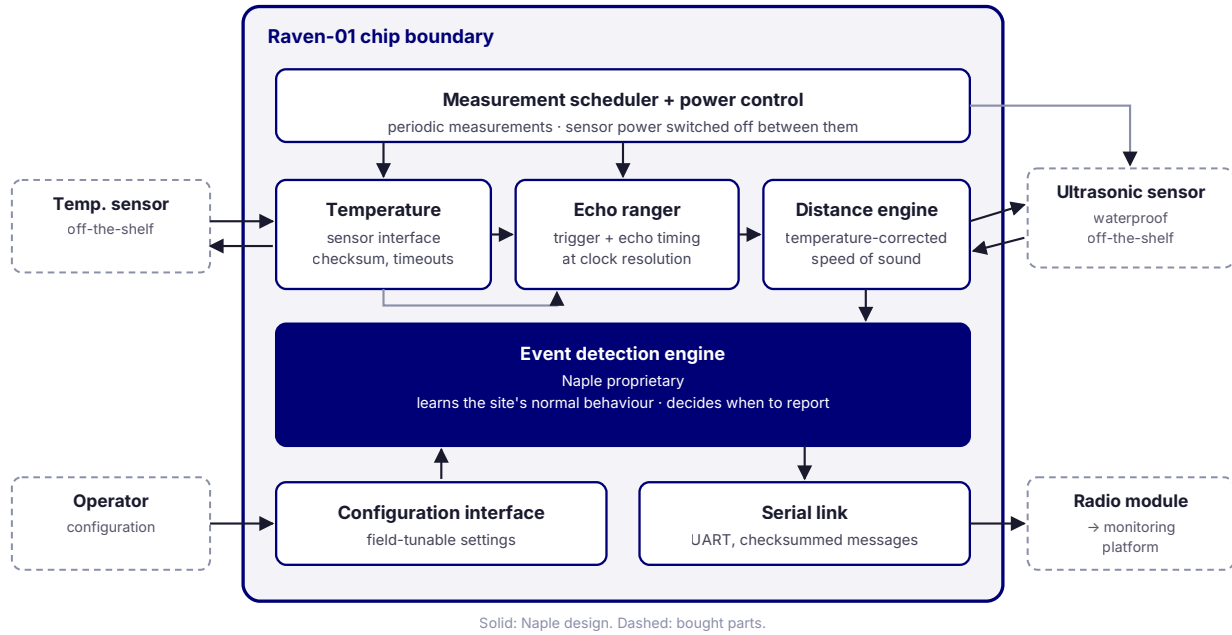


Figure 3. Raven-01 Top-Level Block Diagram

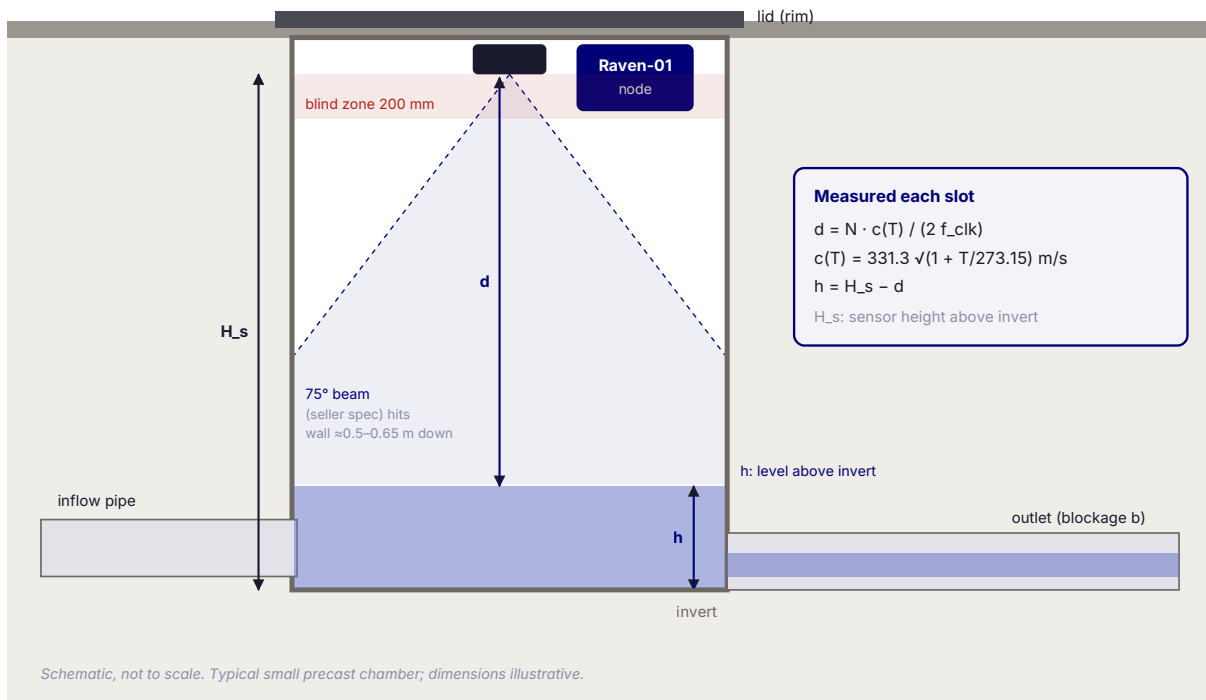


Figure 4. Raven-01 Node in a Manhole: Geometry and Measurement

Temperature-Corrected Echo Ranger

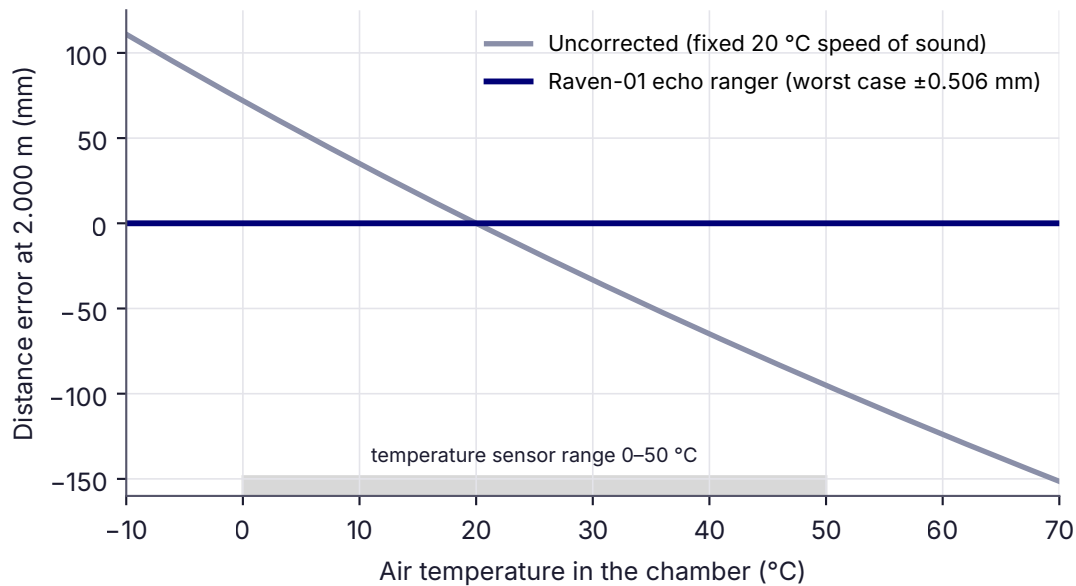
An ultrasonic sensor under the lid returns an echo pulse whose width is the round-trip time of sound to the water. Raven-01 counts that width in clock cycles, N , and converts it with the speed of sound at the measured air temperature:

$$d = N \cdot c(T) / (2 f_{clk}), \quad c(T) = 331.3 \sqrt{1 + T/273.15} \text{ m/s}, \quad h = H_s - d$$

The ideal-gas law is used directly rather than the common linear approximation, which is 0.23 % off at 40 °C. A table of $c(T)$ for every whole degree from –20 to 70 °C is generated at build time and pre-scaled to the clock, so distance is one multiply, add and shift. One clock at 27 MHz corresponds to 6.36 μm of distance **DERIVED**.

The arithmetic was checked exhaustively, for every echo count up to 708,012 clocks and every temperature from –20 to 70 °C: 64,429,183 cases, worst error 0.506 mm **MEASURED**. Without temperature correction, a 10 °C error moves a 2 m reading by about 34 mm.

Humidity is not yet corrected. Near-saturated air makes sound 0.27 to 0.68 % faster between 15 and 30 °C **DERIVED**, about 5 to 14 mm at 2 m. That bias is mostly steady over time.



Uncorrected curve derived from $c(T)$ for a true distance of 2.000 m with 20 °C assumed. Raven-01 band: exhaustive arithmetic check. Error of the ultrasonic sensor itself is not included.

Figure 5. Distance Error With and Without Temperature Correction

Table 2. Raven-01 Measurement Formats

Quantity	Format	Range / resolution
Echo width	unsigned 21-bit, clock cycles	up to 77.7 ms at 27 MHz
Distance, level	unsigned 16-bit, mm	0 – 65,535 mm, 1 mm
Air temperature	signed 8-bit, °C	whole degrees; table covers –20 to 70 °C
Relative humidity	unsigned 8-bit, %	whole percent

Adaptive Normal-Pattern Learning

Sewage flow follows the household day, so a fixed alarm level either misses small changes or trips every morning. Raven-01 learns what is normal for its own manhole over time, on chip, without a server, and keeps a growing problem from being learned as normal. It starts each site with a short learning period and can be told to relearn after maintenance. The method is proprietary to Naple.

On-Chip Event Detection

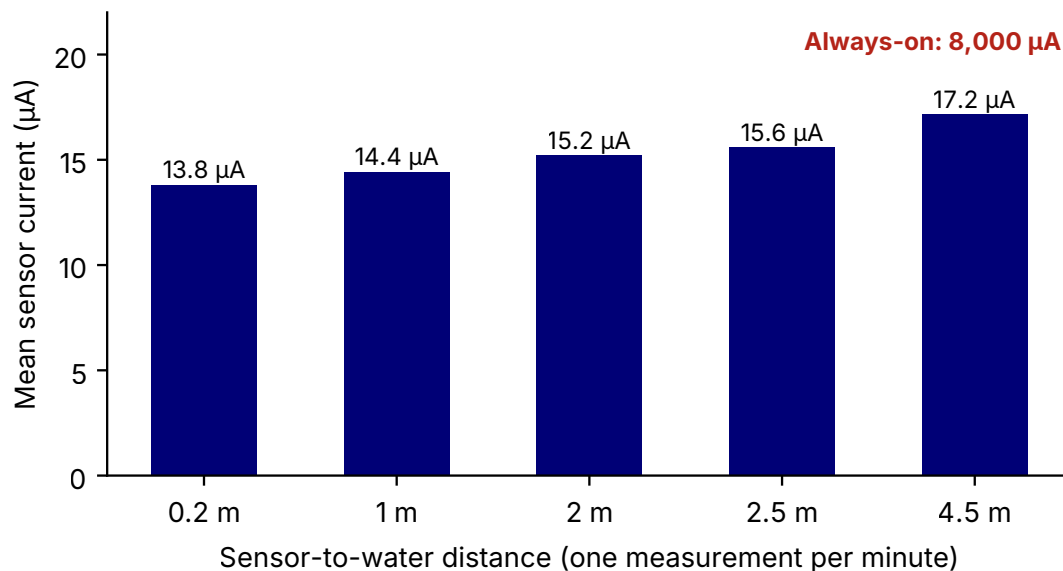
Raven-01 reports four kinds of events, each once when it starts and once when it ends:

- **Developing blockage:** the level stays above its learned normal.
- **Rapid rise:** the level climbs quickly, as after a pump stop or heavy rain.
- **High level:** water approaching the lid, including echoes too close for the sensor to range.
- **Sensor fault:** the sensor stops answering.

A periodic health report carries the current level, so a silent node is itself a signal.

Power-Gated Measurement Scheduler

The ultrasonic module is the most power-hungry part a node could leave switched on. Raven-01 controls its power switch directly, powering the sensor only for each short measurement. At one measurement per minute the sensor is on about 0.2 % of the time, cutting its mean current from 8 mA to 14 to 17 μA **DERIVED**.



Derived from the chip's verified sensor on-time and the sensor seller's quoted 8 mA quiescent current. Sensor warm-up time is not yet confirmed by a datasheet. Chip and radio power are not included.

Figure 6. Mean Ultrasonic Sensor Current Under Raven-01 Power Gating

Self-Checking Serial Link and Field Configuration

Raven-01 talks to its radio module over a standard UART (8N1, 115,200 baud by default). Every message is protected by a checksum, and messages are never interleaved. In simulation the receiver tolerated sender clock offsets from -5.10% to $+5.35\%$ **MEASURED**, far wider than real oscillator drift, and it recovers cleanly after a corrupted frame. Settings can be changed in the field over the same link; the chip checks every change and refuses unsafe values.

Resilience Engine

- **Sensor fault reporting** when the ultrasonic or temperature sensor stops responding.
- **Last-good values:** a failed temperature read never feeds a corrupted value to the distance engine.

- **Health status** available on request, including internal timing and link problems.
- **Build-time checks** stop unusable configurations before they reach hardware.

Raven-01 Specifications

Table 3. Raven-01 Specifications

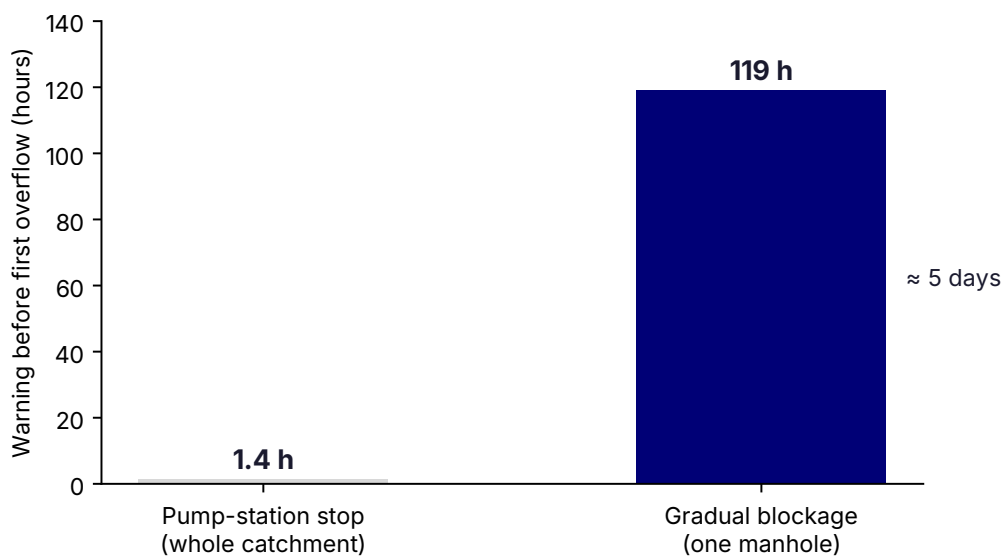
Specification	Raven-01 design	Raven-01 on Tang Nano 9K (GW1NR-9)
Design type	Synchronous digital, single clock, synchronous reset	Same design + board wrapper
Clock	27 MHz reference (parameterised)	27 MHz on-board oscillator
Timing	—	Met at 27 MHz; Fmax 50.3 – 56.7 MHz TOOL
Logic	—	3,428 LUT4 (39.7 %) · 1,655 DFF (25.5 %) TOOL
Memory and DSP	On-chip RAM and ROM	15 RAM16SDP4 · 3 MULT18X18
Level sensing	Ultrasonic echo, 0.20 – 4.5 m (sensor seller spec)	Same
Distance arithmetic	≤ 0.506 mm error MEASURED	Same
Temperature compensation	Ideal-gas c(T), –20 to 70 °C	Same
Events reported	Blockage, rapid rise, high level, sensor fault + health report	Same
Host link	UART 8N1, 115,200 baud, checksummed messages	USB-UART bridge on board
Configuration	Field-tunable, checked writes	Same
Sensor power gating	≈ 0.2 % duty at 1 measurement / min DERIVED	Logic output; external switch
Verification	Byte-exact vs independent model; two simulators	Board-level tests in simulation
Silicon	None yet	—

Raven-01 Detection Performance

Raven-01 was evaluated against a physics-based digital twin of a three-manhole sewer line, built from estimated values for a residential catchment **ESTIMATED**. The results below are the chip design's behaviour in simulation; they are not field measurements, and they will change once real site data and tuning are available.

Days of Warning Before Overflow

≈ 5 days warning of a gradual blockage before the first overflow	0 false blockage alarms over 9 healthy simulated days	1.4 h high-level warning before overflow after a pump-station stop
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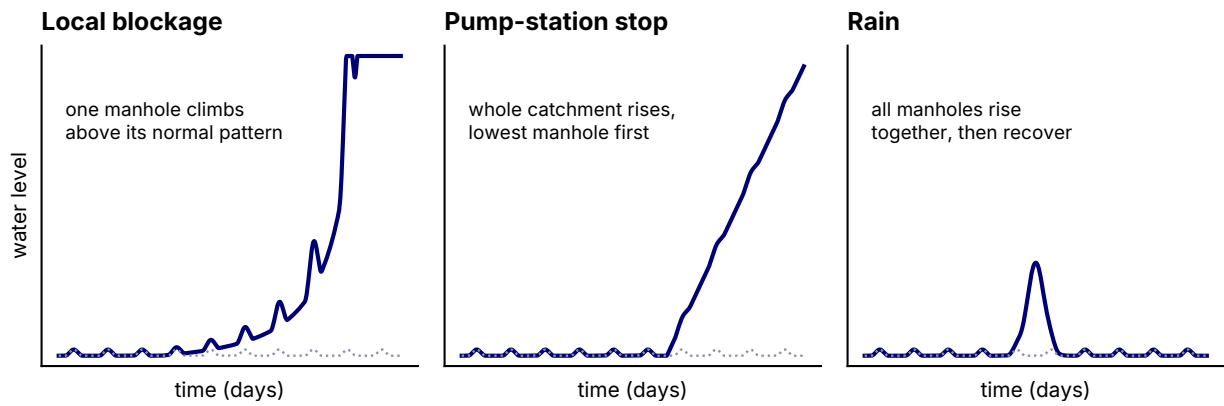
Simulation on estimated sewer values with default settings. Not a field result and not a guarantee of performance.

Figure 7. Raven-01 Warning Time Before First Overflow (simulation)

A full stoppage leaves only hours, as the mass-balance equation predicts. A gradual blockage is where early detection pays: in simulation, Raven-01 flagged it days before the manhole spilled.

Telling Failures Apart

A blockage, a pump stop and a rainstorm all raise water levels, but in different patterns. Each Raven-01 reports its own manhole; a monitoring platform that compares neighbouring nodes can tell the three apart.



Illustrative shapes only, not data.

Figure 8. Three Failure Patterns Raven-01 Is Built to Report

Raven-01 FPGA Prototype Platform

Raven-01's first hardware platform is the Sipeed Tang Nano 9K, built around a Gowin GW1NR-9 FPGA with a 27 MHz oscillator and a USB-to-UART bridge. The design is placed and routed with the open-source flow: Yosys, nextpnr-himbaechel and Project Apicula.

Table 4. Raven-01 Implementation on GW1NR-9 (Tang Nano 9K)

Item	Result
Device	GW1NR-LV9QN88PC6/I5
Tools	Yosys 0.70 · nextpnr-himbaechel 0.11.1 (open source)
LUT4	3,428 / 8,640 (39.7 %)
DFF	1,655 / 6,480 (25.5 %)
ALU	1,536 / 6,480 (23.7 %)
MULT18X18	3 / 20 (15 %)
RAM16SDP4	15 / 270 (5.6 %)
Timing at 27 MHz	Met on four placement seeds
Post-route Fmax	50.3 – 56.7 MHz across seeds

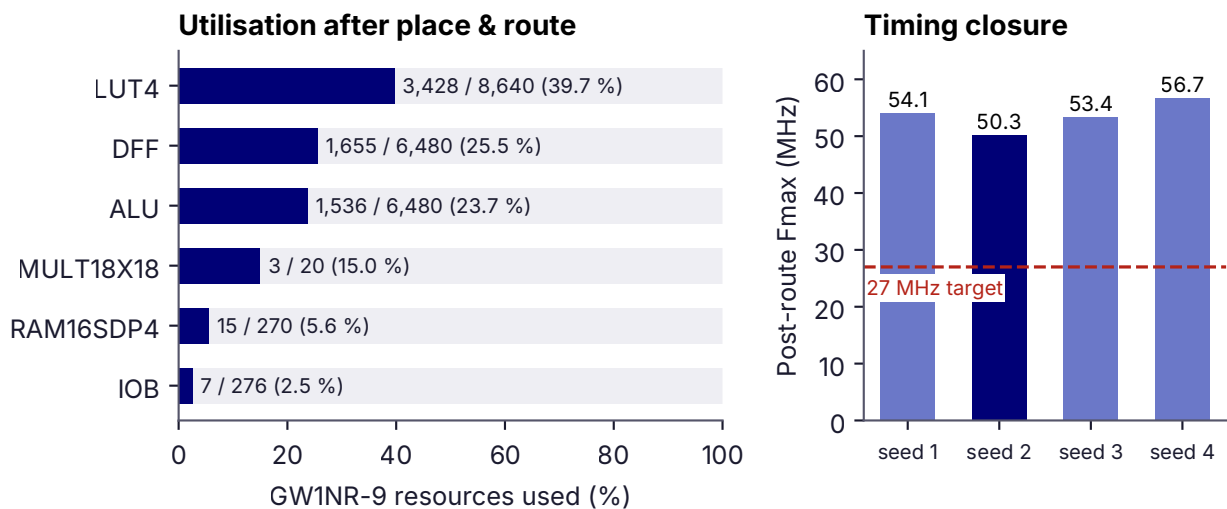
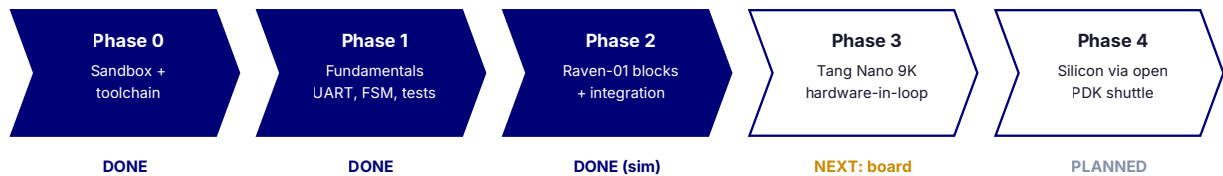


Figure 9. Raven-01 Resource Use and Timing Closure on GW1NR-9

Raven-01's Role in Naples Semiconductor

Raven-01 is Naples's reference design. It set the way Naples builds chips: physics first, an independent reference model before the hardware description, byte-exact verification in two simulators, tests proven able to fail, and an honest label on every number.



Phase 3 goal: the design on a Tang Nano 9K reads a real off-the-shelf sensor. Phase 4 goal: a Naples design on a shared open-process silicon run. Dates are not committed.

Figure 10. Naples Chip Roadmap and Raven-01's Position

Path to Silicon

Naples is a fabless design company. Raven-01 uses about 40 % of a small FPGA and runs at 27 MHz, which makes it a candidate for a shared multi-project silicon run on an open process design kit, where many designs split one mask set. No silicon run has been scheduled, and costs will be confirmed with the programme before any commitment.

Appendix A

Engineering Record

Table 5. Raven-01 Key Assumptions

Assumption	Effect if wrong
Sewer values in the simulation (chamber size, flow, households) are estimates	Warning times change
Ultrasonic sensor timing taken from seller information; datasheet pending	Power figures change
Sound speed uses dry air; humidity not corrected	5 – 14 mm steady level bias at 2 m
Ultrasonic sensor error not yet measured on a real sensor	Smallest detectable change unknown

Table 6. Raven-01 Verification Record

Check	Outcome
Distance arithmetic, exhaustive 64,429,183 cases	Max error 0.506 mm
Worked value: 5,827.26 μ s echo at 20 °C	1000.0 mm; 965.3 mm at 0 °C
Design vs independent reference model	Byte-identical in all tested scenarios
Mutation testing (deliberately planted bugs)	All caught
Full regression, Verilator and Icarus	Pass
Lint (Verilator -Wall)	0 warnings
FPGA timing at 27 MHz	Met, four seeds
Hardware and field tests	Not yet done

Table 7. Nomenclature

Symbol	Meaning	Unit
h	water depth above the manhole invert	mm
d	sensor-to-water distance	mm
H_s	sensor height above the invert	mm
N	echo width in clock cycles	clocks
c(T)	speed of sound in air	m/s
T	air temperature	°C
A_m	chamber plan area	m ²
Q_{in}	inflow to the chamber	m ³ /s
t_w	warning time from alarm to overflow	s

References

- Global Precast, SANS 1294 manhole components (chamber sizes 1,000 – 2,000 mm).
- Sipeed Tang Nano 9K documentation and example projects, github.com/sipeed/TangNano-9K-example.
- YosysHQ Yosys; nextpnr-himbaechel; Project Apicula (open-source Gowin flow).

In Plain Words

Raven-01 is a chip design made by Naple. It sits in a sewer manhole and watches the water level.

It sends sound down to the water and times the echo. It also checks the air temperature, because sound moves faster in warm air. That keeps its maths accurate to about half a millimetre.

The chip learns what is normal for its manhole. When something changes, like a slow blockage, a fast rise, water near the lid or a broken sensor, it sends a short message. In a computer test, it warned about five days before a blocked manhole overflowed.

It switches the sensor on only for a moment each minute, to save battery.

So far it has been tested in computer simulation and FPGA design tools. It has not yet run on a real board or in a real sewer, and no chip has been made yet.

Notice

This brief describes a design under development and is believed to be accurate as of 21 October 2026. Naple Technologies ("Naple") gives no representation or warranty, expressed or implied, as to its accuracy or completeness, and accepts no liability for consequences of its use. Naple may change this brief, or the design it describes, at any time without notice.

Development status. Raven-01 has been verified in simulation and implemented in FPGA design tools only. No hardware has been run and no silicon exists. Performance figures are simulation results on estimated values; they are not field measurements and not a guarantee of performance.

Not for safety-critical use. Raven-01 is not designed, qualified or warranted for medical, military, aerospace, life-support or other applications where failure could cause injury, death, or serious property or environmental damage, and it is not a substitute for inspection or maintenance.

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