



**ELECTROMAGNETIC 2 AXIS WATER CURRENT METER INTEGRATION FOR
ORIGINAL EQUIPMENT MANUFACTURERS (OEM)**

ARDUINO MKR SERIES (WiFi 1010, WAN 1310, GSM 1400, NB 1500)

7/9/2025

Advancing Water Current Measurement: Introducing the Two-Axis Electromagnetic Sensor System

Executive Summary

In an era where precise environmental monitoring is critical for industries such as marine research, hydrology, aquaculture, and renewable energy, accurate measurement of water currents remains a foundational challenge. Traditional mechanical sensors often suffer from fouling, calibration drift, and limited integration capabilities, leading to unreliable data and increased operational costs.

This white paper introduces an innovative two-axis electromagnetic water current meter designed to address these pain points. Featuring a compact one-inch spherical sensor probe wired to a sophisticated printed circuit board (PCB), the system leverages electromagnetic principles for solid state, high-accuracy velocity measurements in two dimensions. The PCB is divided into a proprietary processing layer that handles raw sensor data and a user-accessible layer based on the Arduino MKR WiFi 1010 microcontroller, enabling seamless integration for original equipment manufacturers (OEMs).

Key benefits include:

High Precision and Reliability: Electromagnetic sensing eliminates moving parts, reducing maintenance and ensuring consistent performance in harsh aquatic environments.

Easy Integration: OEMs can effortlessly connect to cloud-based dashboards for real-time data visualization or incorporate the sensor into multi-sensor arrays for comprehensive system development.

Scalability: Wireless connectivity via WiFi, cellular, LoRa supports IoT deployments, from standalone monitoring stations to large-scale networks.

By empowering OEMs with a flexible, plug-and-play solution, this sensor system accelerates innovation in water resource management, environmental protection, and industrial applications.

Introduction

Water currents play a pivotal role in numerous sectors, influencing everything from ocean circulation models and flood prediction to turbine efficiency in hydroelectric plants and fish farm optimization. However, measuring these currents accurately has historically been fraught with challenges. Mechanical meters and acoustic Doppler current profilers (ADCPs), while effective in certain scenarios, often require frequent maintenance due to biofouling, suffer from directional limitations, and pose integration hurdles for custom systems.

The need for a robust, low-maintenance alternative has driven the development of electromagnetic-based sensors. Electromagnetic current meters operate on Faraday's law of electromagnetic induction, where the motion of conductive fluid (such as seawater or freshwater) through a magnetic field generates a measurable voltage proportional to the flow velocity. This non-contact method avoids the pitfalls of mechanical wear and provides superior accuracy in turbulent or sediment-laden waters.

Aqua Magnetic's two-axis electromagnetic water current meter: a compact, versatile solution that measures velocity along two orthogonal axes (typically X and Y, for horizontal plane analysis). This white paper explores the design, functionality, and applications of this sensor system, highlighting its proprietary PCB architecture that bridges advanced signal processing with user-friendly Arduino-based customization. Tailored for OEMs, it facilitates data transmission to cloud platforms or integration into broader sensor ecosystems, unlocking new possibilities for data-driven decision-making.

Technology Overview

Electromagnetic Sensing Principle

At the heart of the system is the electromagnetic sensing mechanism. The sensor generates a stable magnetic field within the surrounding water. As water flows past the sensor, charged particles (ions in the conductive fluid) experience a Lorentz force, inducing a voltage across electrodes positioned perpendicular to both the magnetic field and the flow direction.

For a two-axis configuration:

X-Axis Measurement: Detects velocity in the primary flow direction.

Y-Axis Measurement: Captures lateral or cross-flow components, enabling vector-based analysis of current direction and magnitude.

This dual-axis approach provides a comprehensive 2D velocity profile, essential for applications requiring directional accuracy, such as navigation aids or current mapping in rivers and estuaries. The system's sensitivity allows for detection of velocities ranging from 0.05 fps to over 15 fps, with resolutions down to 0.01 fps, depending on environmental conductivity.

Unlike single-axis sensors, this design minimizes errors from off-axis flows, offering a more holistic view of fluid dynamics without the need for mechanical orientation adjustments.

Sensor Design

The physical sensor is a one-inch diameter spherical ball, engineered for minimal hydrodynamic drag and optimal field uniformity. Constructed from durable, non-corrosive materials (e.g., epoxy-encased coils and electrodes), the ball houses:

- A compact electromagnet for field generation.

- Orthogonal electrode pairs for voltage detection.

- Proprietary shielding, and manufacturing for optimal readouts

The sphere is wired directly to the PCB via a shielded cable, ensuring signal integrity over distances up to 30 ft. This wired connection prioritizes reliability in submerged or remote deployments, avoiding the power and interference issues common in wireless underwater links.

PCB Architecture: Proprietary and User Layer

The system's intelligence resides in a multi-layer PCB that decouples core processing from user customization, striking a balance between proprietary innovation and open accessibility.

Proprietary Layer

This embedded layer is responsible for raw data acquisition and preprocessing:

Signal Conditioning: Amplifies and filters the induced voltages to remove noise from electromagnetic interference (EMI).

Data Calibration: Applies proprietary algorithms to convert voltage readings into calibrated velocity vectors.

Error Detection: Real-time conductivity diagnostics

Interface Protocol: Outputs processed data (e.g., velocity magnitude, direction, and metadata) via a standardized serial interface (e.g., I2C or UART) to the user layer.

By handling these complex tasks internally, the proprietary layer shields OEMs from low-level engineering, allowing focus on application-specific development.

User Layer: Arduino MKR WiFi 1010 Integration

Built atop the Arduino MKR WiFi 1010—a compact, low-power microcontroller with built-in WiFi and Bluetooth—the user layer provides an open platform for customization:

Microcontroller Specs: SAMD21 Cortex-M0+ 32-bit processor at 48 MHz, 256 KB flash, 32 KB SRAM, supporting Arduino IDE for rapid prototyping.

Connectivity Options: Native WiFi (802.11 b/g/n) for cloud uploads, Bluetooth Low Energy (BLE) for local pairing, and GPIO pins for sensor expansion.

Power Management: Operates on 3.3V with low consumption (under 100 mA during transmission), ideal for battery-powered buoys or remote stations.

OEMs receive the processed data stream and can:

Develop Custom Firmware: Use Arduino sketches to aggregate data, apply filters, or trigger alerts.

Cloud Integration: Leverage libraries like ArduinoIoTCloud or MQTT to send data to platforms such as AWS IoT, Google Cloud, or custom dashboards for real-time visualization and analytics.

Sensor Array Expansion: Interface with additional sensors (e.g., pH, turbidity, or GPS) via I2C/SPI ports, creating integrated monitoring systems.

This layered approach ensures intellectual property protection for the core technology while empowering OEMs with the flexibility of an established ecosystem.

Features and Benefits

Key Features

Compact Form Factor: One-inch sensor ball and credit-card-sized PCB for easy deployment in confined spaces.

High Accuracy: $\pm 1\%$ full-scale error, with electromagnetic immunity to particulates and algae.

Versatile Powering: USB, battery, or solar options via the MKR board.

Data Output: JSON-formatted packets including velocity (m/s), direction (degrees), timestamp, and diagnostics.

Environmental Resilience: IP68-rated enclosure for submersion up to 100 meters.

Benefits for OEMs and End-Users

Reduced Time-to-Market: Pre-processed data and Arduino compatibility accelerate prototyping.

Cost Efficiency: No moving parts minimize maintenance; cloud integration enables predictive analytics to prevent failures.

Scalable Deployments: From single-node setups to networked arrays, supporting applications like smart cities or offshore wind farms.

Data Security: Encrypted transmissions and local storage options comply with standards like GDPR for sensitive environmental data.

Applications and Use Cases

This sensor system excels in diverse scenarios:

Oceanography and Hydrology: Mapping river currents for flood modeling or studying tidal flows in coastal zones.

Aquaculture: Monitoring water circulation in fish pens to optimize oxygenation and feed distribution.

Renewable Energy: Assessing site suitability for tidal turbines by providing precise 2D velocity data.

Environmental Monitoring: Integrating into buoys for pollution tracking or ecosystem health assessments.

Industrial Integration: OEMs can embed the sensor in autonomous underwater vehicles (AUVs) or combine with sonar for enhanced navigation.

For instance, an OEM developing a smart buoy could use the user layer to fuse current data with wave height sensors, uploading aggregates to a cloud dashboard for remote fleet management.

Integration Guide for OEMs

Getting started is straightforward:

- 1. Hardware Setup:** Connect the sensor ball to the PCB via the provided cable.
- 2. Firmware Development:** Install the Arduino IDE, load sample sketches for data reading, and customize as needed.
- 3. Cloud Connectivity:** Configure WiFi credentials and API keys for your preferred platform.
- 4. Testing and Deployment:** Use built-in serial monitors for validation; deploy in field trials with optional enclosures.

Comprehensive documentation, including API references and example code, is available to support seamless adoption.

Conclusion

The two-axis electromagnetic water current meter represents a leap forward in fluid dynamics measurement, combining cutting-edge sensing with accessible integration tools. By processing data through a proprietary layer and exposing it via the Arduino MKR WiFi 1010, this system empowers OEMs to innovate without reinventing the wheel—whether sending insights to cloud dashboards or building sophisticated sensor arrays.

We invite OEMs and researchers to explore partnerships for custom adaptations or pilot programs. Contact us to discuss how this sensor can elevate your projects.

For more information, visit our website or reach out to our technical team.

www.aqua-magnetics.com

****Disclaimer:**** This white paper is for informational purposes only. Specifications are subject to change based on ongoing development.