

# Abstract

**The Continuous Anti-Xa Sensor Module transforms heparin management by embedding an aptamer-based electrochemical biosensor in a plug-and-play arterial-line bypass cartridge. A redox-tagged DNA aptamer on a gold micro-band electrode transduces anti-Xa binding into current shifts, delivering minute-by-minute readings across 0–1.2 IU mL<sup>-1</sup> with a 0.05 IU mL<sup>-1</sup> limit-of-detection and sub-30 s response time. The 30 × 10 × 5 mm disposable houses a micropump for auto-flush/calibration, copper EMI shielding, EEPROM dose ceilings and RFID lot control, and streams data via I<sup>2</sup>C to the TraceLoop-MX controller. A hierarchical PID/MPC algorithm titrates unfractionated heparin in ≤10 % steps and, on overdose (>0.8 IU mL<sup>-1</sup>), triggers a protamine micro-infusion while enforcing hard infusion caps. Five-day biocompatible operation, antifouling hydrogel, and fail-safe interlocks ensure ICU-grade reliability. By closing the measurement-actuation loop, the module reduces thrombotic and bleeding risks and brings precision anticoagulation to critical-care automation.**