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Design Your Next-Generation Medical Pump with ADI Solutions

Modern medical pumps must deliver accurate, repeatable therapy while operating under strict safety, reliability, and power constraints. Meeting these requirements depends on tight integration of sensing, signal conditioning, motion control, processing, power management, isolation, and connectivity. As pump designs expand across clinical and home-care settings, manufacturers need advanced electronics to improve measurement integrity, control performance, and system robustness. Analog Devices, Inc. (ADI) supports medical pump design across sensing, signal conditioning, motion control, processing, power management, isolation and connectivity. This overview is intended for medical pump system architects and design engineers designing fluid-delivery and extracorporeal-therapy platforms for clinical and home-care use.

Medical pumps support a broad range of therapies and use cases, with requirements that vary by application and care setting. Infusion pumps deliver controlled volumes of fluids, medications, and nutrients into a patient's circulatory system, with rates spanning from microliters per hour in syringe pumps to liters per hour in large-volume systems. Increasingly, infusion therapy is moving beyond hospitals into ambulatory and home-use environments, enabling continuous treatment while supporting patient mobility.

Dialysis systems act as artificial kidneys for patients with temporary or permanent renal failure. During hemodialysis, blood is continuously circulated, filtered, and rebalanced to regulate electrolytes, pH, and fluid levels. While traditional dialysis platforms are used under clinical supervision, newer home-use systems can provide greater scheduling flexibility and may support improved outcomes through more frequent or extended sessions.

Together, these use cases drive system requirements across precision sensing, low-noise signal chains, reliable actuation, deterministic control, robust power/isolation, and secure connectivity. The following sections outline the key electronic building blocks that enable scalable, patient-centric medical pump designs.

Precision Sensing and Signal Conditioning

Medical pump operation depends on accurate, repeatable measurement throughout the fluid path, often at multiple points in the extracorporeal circuit. Common needs include flow, pressure, temperature, and oxygen saturation, plus safety detection—for example, occlusion and air-in-line.

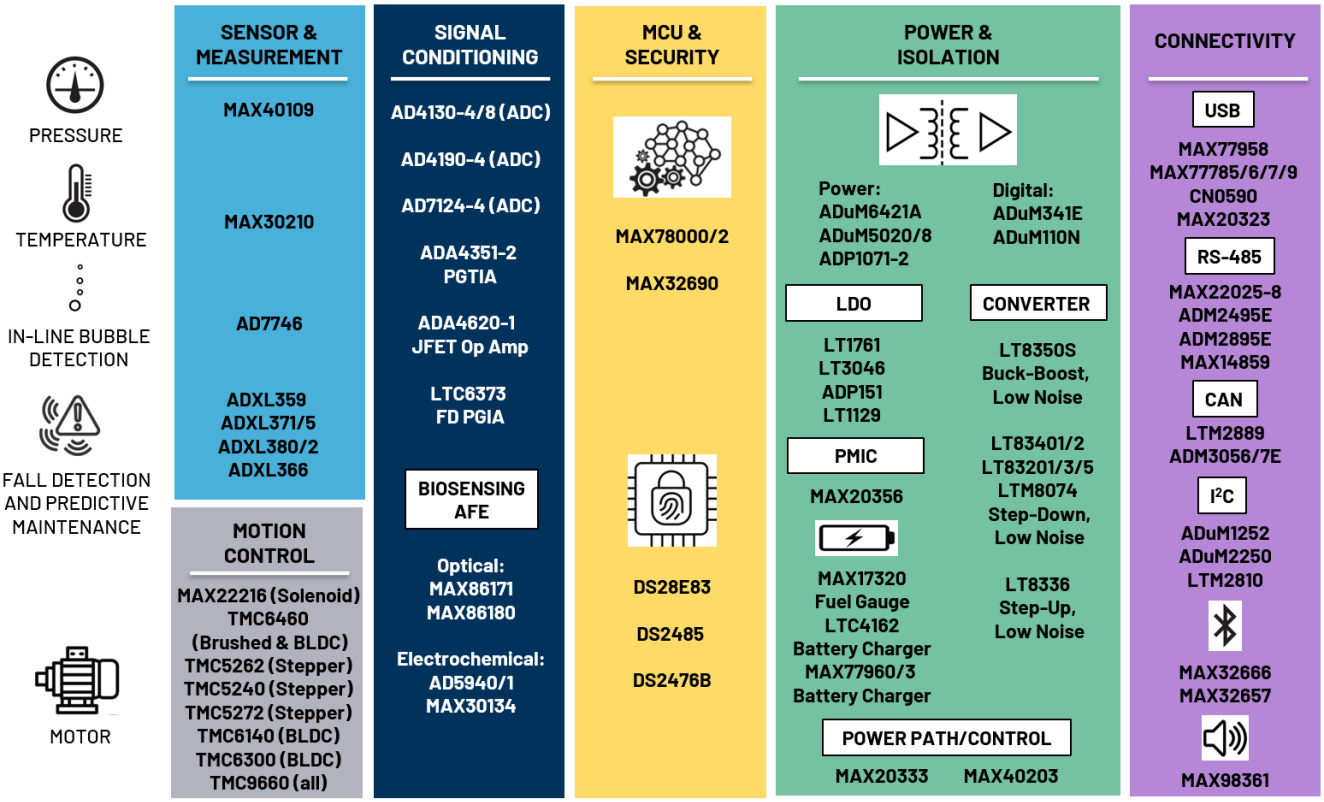

Figure 1. Whether it's a single component or an end-to-end integrated solution, ADI offers a spectrum of options designed for your medical application.

In practice, overall accuracy is often limited by the signal chain as much as the sensor. Low-level sensor outputs must be conditioned, protected, and converted with minimal added noise and drift so the system can maintain accuracy over time, across temperature, and in the presence of interference from motors and switching power supplies. ADI supports these designs with precision analog front ends and signal-conditioning solutions optimized for low noise, high stability, and low power in medical sensor interfaces.

MAX40109
Pressure Sensor

- Zero-pressure offset compensation enables single-flow calibration
- No need for thermistors (PTC)
- 6.15mm^2

For pressure sensing, the MAX40109 analog front end (AFE) streamlines pressure sensor manufacturing by enabling single-pass calibration, reducing complexity, manufacturing time, and calibration cost while supporting accurate pressure monitoring throughout fluid delivery path.

To digitize conditioned signals with high fidelity, ADI offers high-performance analog-to-digital converters (ADCs) such as the AD4130-4/AD4130-8, AD4190-4, and AD7124-4. When paired with precision amplifiers like the ADA4620-1 and programmable-gain instrumentation amplifiers such as the LTC6373, these devices deliver the resolution and throughput needed for both steady-state measurements and rapid detection of safety-critical events.

AD4130-8
ADC

- Ultra-low power
- Enhanced digital features
- Autonomous sensor measurement capabilities

Beyond pressure and flow, optical and electrochemical sensing can extend both safety coverage and therapy insight in medical pump platforms. Typical functions include drip monitoring, blood biomarker measurement, and pH tracking during infusion or dialysis. For optical sensing, the MAX86171 and MAX86180 provide low-power solutions that integrate the optical front end (LEDs and photodiodes), supporting portable and battery-powered designs. For electrochemical sensing, the AD5940/AD5941 and MAX30134 provide high-performance AFEs for applications such as glucose monitoring and chemical analysis within fluid delivery systems.

AD5940/AD5941
Electrochemical AFE

- High precision, low power
- Measures high bandwidth signals up to 200kHz
- Techniques, such as amperometric, voltammetric, or impedance measurements

Finally, MEMS vibration sensing can improve robustness and serviceability by detecting drops, shocks, and abnormal vibration signatures that may indicate wear or impending failure. Devices such as the ADXL371, ADXL366, and ADXL359 enable condition-based monitoring to support predictive maintenance, reduce unplanned downtime, and improve overall system uptime.

Advanced Motion Control Technology

Motion control is fundamental to medical pumps, driving peristaltic mechanisms for blood and dialysate, syringe actuators for precise dosing, and valves/clamps/latches that regulate fluid paths. Across home-care and intensive-care use, designs must be compact and energy efficient while maintaining smooth, low-noise operation and repeatable low-speed motion. ADI motion-control solutions address these needs with motion profiling, efficient current regulation, and built-in protection/diagnostics suited for regulated healthcare equipment. These characteristics directly affect dosing accuracy, pulsation, acoustic noise, and power consumption.

TMC5262
Stepper Motor Driver

- Silent and smooth operation
- Load-dependent current
- Advanced control methods
- Advanced diagnostic function
- 36mm^2

The TMC5262 is a miniaturized, high-power, single-axis stepper motor controller and driver IC designed for space-constrained pump architectures. It combines advanced control features with rich diagnostics to support smooth, predictable motion and system insight. Key capabilities include near-silent operation with high efficiency, precise torque control, and suppression of mid-range resonances to reduce vibration and pulsation while maintaining accurate positioning.

For valve blocks, clamps, latches, and other actuators, the MAX22215 / MAX22216 / MAX22217 integrate functions that improve solenoid and DC motor drive performance and efficiency. A two-level sequencer delivers high pull-in current for fast actuation, then automatically transitions to a lower hold current to reduce power and heating. Drive-signal ramping helps minimize acoustic noise and mechanical shock, while a dither function can improve small-signal repeatability. Built-in diagnostics support reliability and predictive maintenance, including plunger movement detection; inductance and travel-time measurement; open-load detection; and real-time current monitoring.

MAX22215/MAX22216/MAX22217
Solenoid Driver

- Power saving
- Flexibility and configurability
- Advanced control methods
- Advanced diagnostic function
- 10mm^2

Intelligent Processing and Control

Modern medical pumps require sophisticated processing capabilities to manage multiple sensors, control complex mechanisms, implement safety protocols, and provide intuitive user interfaces. These functions must be implemented with deterministic performance and high reliability to maintain accurate therapy delivery across clinical and home-care environments. At the system level, the processor closes the loop between sensing and actuation. It filters sensor data,

executes control algorithms, enforces safety limits, and logs events for traceability.

On-device analytics can support local algorithms such as anomaly detection and predictive monitoring. The MAX78000/MAX78002 AI microcontrollers integrate an ultra-low-power convolutional neural network accelerator to run these workloads on the device, reducing latency and helping limit the amount of high-rate raw sensor data that must be transmitted off-system.

MAX78000/MAX78002
AI MCU

- Neural network accelerator
- High system integration
- Advanced power management

Secure low-power wireless links enable remote monitoring, configuration, and data transfer in connected pump designs. The MAX32666 and MAX32657 integrate Bluetooth® Low Energy 5 for this purpose, and the MAX32657 (a nano-Power Arm® Cortex®-M33 MCU with Bluetooth LE) is especially well suited for portable and wearable platforms where battery life and compact integration are key.

MAX32657
MCU

- Nano-power
- Arm Cortex-M33 MCU
- Bluetooth LE 5.4
- 6.87mm^2

Power Management and Isolation

Power management and isolation directly affect sensor accuracy, actuator performance, and patient protection in medical pump systems. ADI's power and digital isolation solutions help designers achieve efficient conversion, low ripple/noise, and galvanic isolation while meeting reliability requirements in clinical and home-care environments.

The ADuM341E quad-channel 150Mbps digital isolator provides galvanic isolation up to 1173V peak with low propagation delay for low-latency, low-jitter timing. The LT83401 and LT83402 synchronous step-down regulators provide efficient conversion and low-ripple supply rails suited for sensitive analog and mixed-signal circuitry.

ADuM341E
Isolator

- CMTI > 150kV/µs
- Surge >16kV
- 7.19ps typical random jitter
- 6.2ns typical propagation delays

For battery-powered pumps, the MAX17320 is a 38µA I_Q standalone pack-side fuel gauge with protector for 2 to 4 series lithium-ion or lithium-polymer batteries. It monitors voltage, current, temperature, and state-of-charge to enable accurate gauging and comprehensive pack protection, including overvoltage and undervoltage, overcurrent and short-circuit, overtemperature and undertemperature, overcharge, and internal self-discharge conditions, with optional SHA-256 authentication. With stable power rails

and isolation in place, connected interfaces can be added for monitoring, configuration, and data exchange.

MAX17320
Fuel gauge

- Overvoltage (temperature dependent)
- Overcharge/overdischarge/short-circuit current
- Over/undertemperature
- Percent, capacity, time-to-empty/full, age

Connectivity and Data Management

Contemporary medical pumps must support data logging, remote monitoring, and interoperability with clinical systems, while also addressing security and maintainability requirements such as authentication and firmware updates. ADI provides interface solutions spanning USB, RS-485, and serial communications to support both modern connectivity needs and integration with legacy medical IT infrastructure.

Isolated RS-485 transceivers help maintain signal integrity and protect electronics in the presence of ground shifts, electromagnetic interference (EMI), and cable faults. The ADM2895E, for example, is a 5.7kV signal and power isolated RS-485 transceiver with ±60V fault protection on the RS-485 A and B pins, supporting reliable communication in demanding clinical environments.

ADM2895E
Isolated RS-485

- Compact half duplex + power
- ±60V protection against shorts to 24V supplies
- High EMC robustness on bus pins

USB-C interfaces also benefit from robust protection against overvoltage and surge events. The MAX20323 family of overvoltage protectors integrates an internal overvoltage threshold and surge protection that turns off the switches during fault conditions to help prevent damage to USB Type-C pins, while providing 0.27Ω (typ) on-resistance when operating below the overvoltage threshold.

MAX20323
USB Type-C CC-Pin Overvoltage Protector

- Flexible system design: 2.5V to 5.5V
- Reliable protection with accurate overvoltage lockout (OVLO) threshold and surge immunity
- Ultra-fast turn-off: 100ns (typ)
- Space saving

Conclusion

Medical pump design demands careful integration of precision sensing, reliable actuation, deterministic control, robust power and isolation, and secure connectivity. ADI supports these requirements with a broad portfolio that helps improve measurement integrity, control performance, manufacturability, and long-term reliability. By combining accurate sensor interfaces, advanced motion control, intelligent processing, efficient power conversion with

galvanic isolation, and dependable data connectivity, designers can accelerate development of next-generation infusion and dialysis platforms that deliver safe, scalable, patient-centric therapy.

About the Author

Mariam Momenzadeh is part of the marketing team in Analog Devices' Healthcare Business Unit, where she focuses on driving business and innovation growth through customer-centric engagements within therapy/acute care, implantable, and X-ray markets. She holds a master's degree in engineering and management from the Massachusetts Institute of Technology, a Ph.D. in computer engineering with a minor in electrical engineering from Northeastern University, and a master's in computer science and engineering from the University of Connecticut.

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