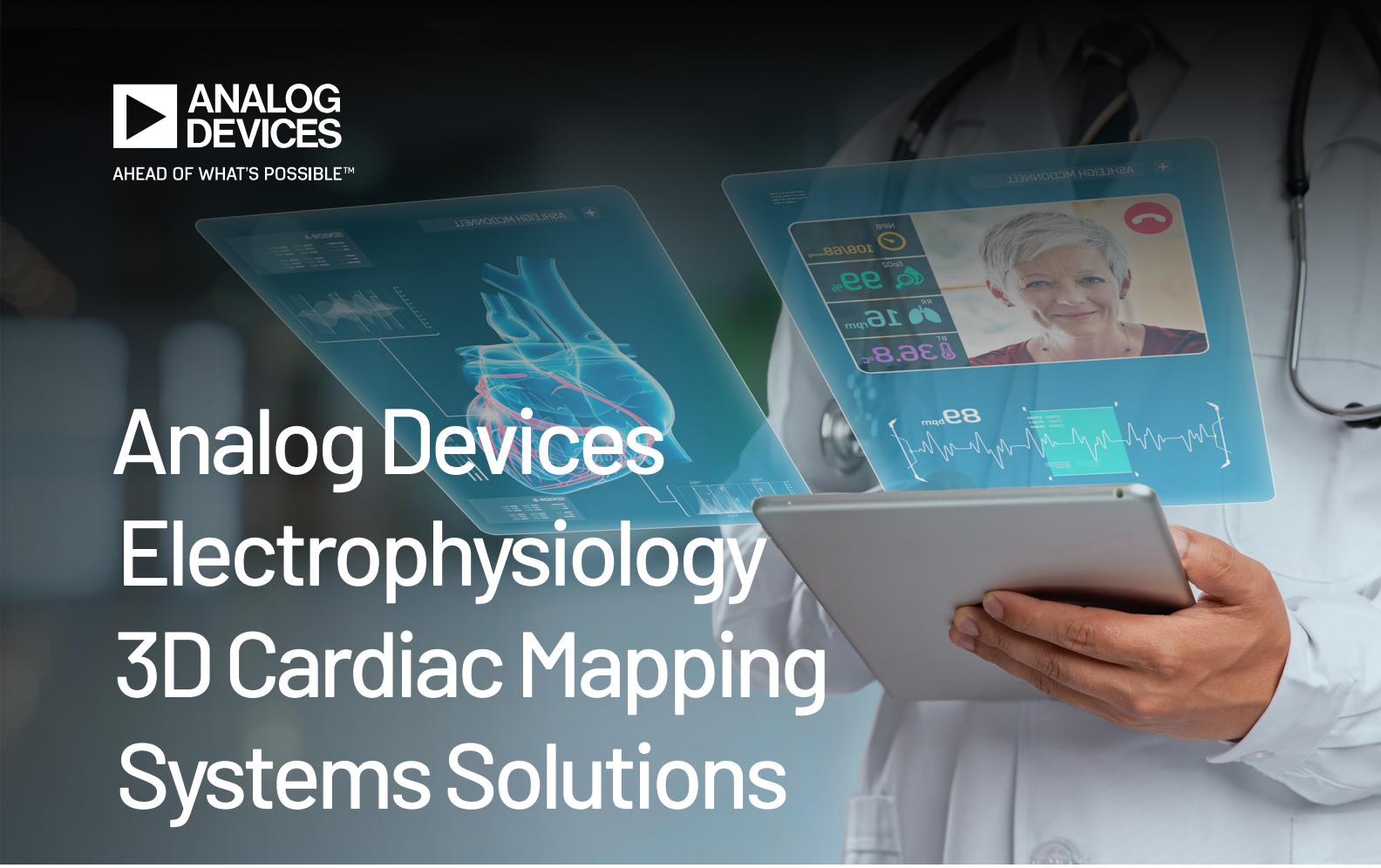
ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™



Analog Devices Electrophysiology 3D Cardiac Mapping Systems Solutions

Electrophysiology System Theory and Typical Architecture

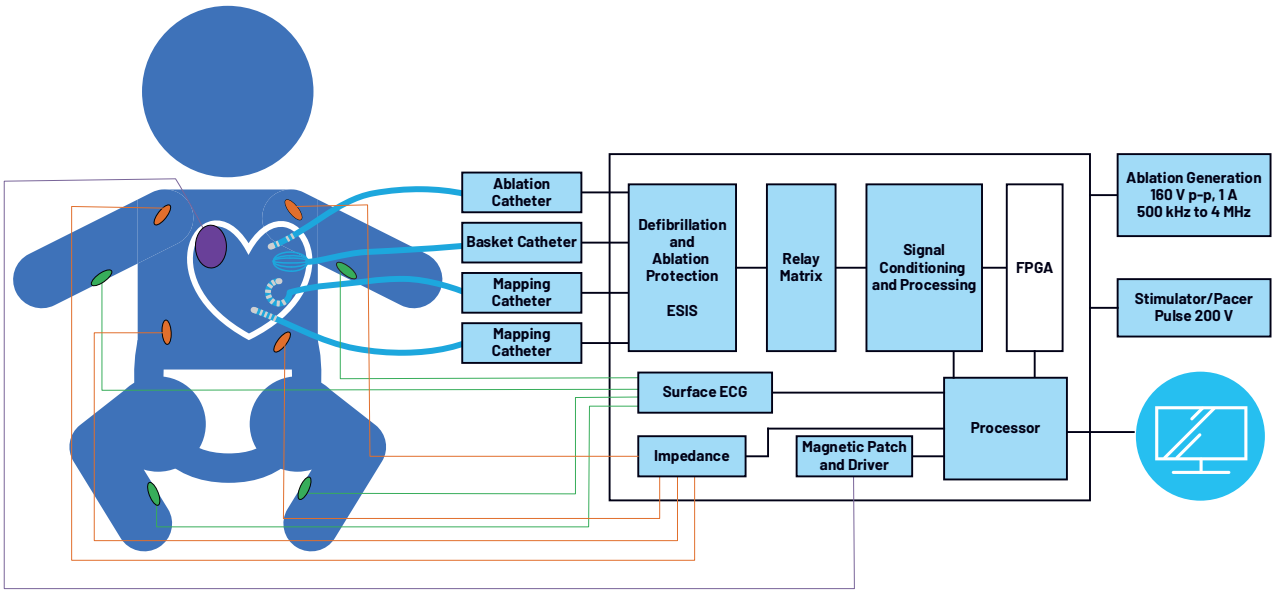
An electrophysiology (EP) device is system used to perform a test to assess the heart's electrical system or activities and to diagnose abnormal heartbeats or arrhythmia. The test is performed by inserting catheters and wire electrodes, which measure electrical activities, through blood vessels that enter the heart. Catheter ablation is a technique used to treat arrhythmia, an abnormal heart rhythm created by a disturbance in the heart's electrical system. Catheter ablation destroys or disrupts parts of the electrical pathways causing the arrhythmias.

The electrophysiology mapping and imaging systems use mapping catheters that contain electrodes to measure the electrical activity of the cardiac tissue. The signals from the electrodes of different catheters pass the protection circuits and then enter the signal conditioning and processing circuits. The processed data is transferred to the system software where a 3D model is created of the heart, a color-coded overlay showing the electrical waves generated during each heartbeat, the touch points where the tissue was mapped, and showing the location of the catheter inside the heart. Tissue identified as having unhealthy electrical activity that is cause an arrhythmia can then be ablated directly or isolated using an ablation catheter to cause small burns/scar tissue that block electrical signals.

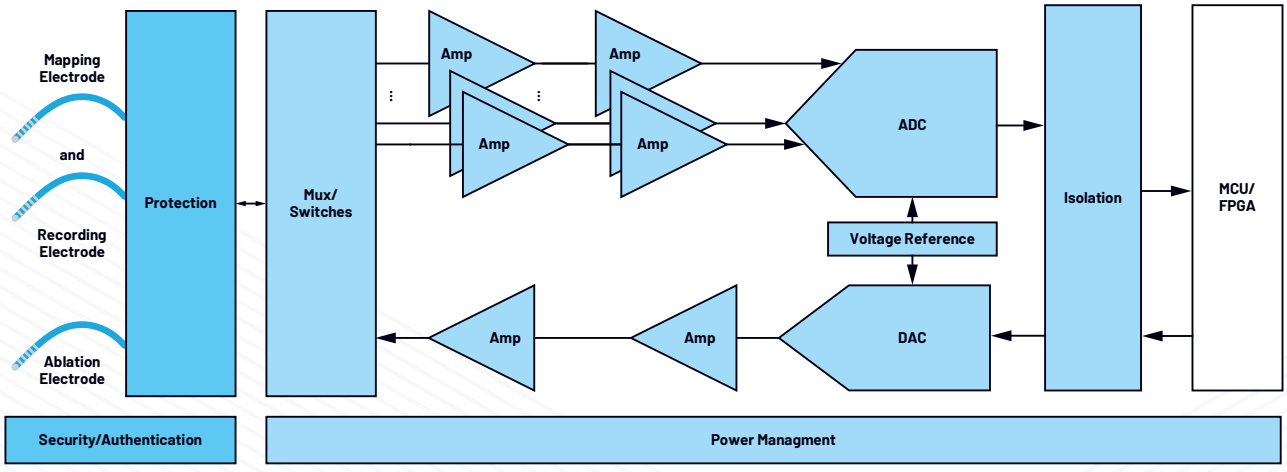
Electrophysiology System Design Considerations and Major Challenges

- Safety: Isolation of Data and Power. The device must meet patient safety standards for leakage current <10 µA, so the electric isolation of power and data from patient connections is a mandatory safety requirement.
- Small Signals. The typical signal is 25 µV (as measured in infracted regions during ventricular tachycardia mapping) to 5 mV (from a surface ECG lead), which allowed for a noise floor of <10 µV
- Reducing Form Factor. There are 10 to 256 or even more electrodes on a mapping catheter, with a typical ring electrode size that is 1 mm or smaller, edge-to-edge spacing between each electrode that can be less than 1 mm, and the need for a mapping catheter to be steerable and even smaller.
- Increasing Number of Interferers. The EP operation room is an extraordinarily noisy environment. The patient is connected to multiple pieces of equipment including an ECG, a pulse oximeter, an external defibrillator, an electroanatomic mapping system, an ablation generator, and intracardiac catheters, and sometimes an infusion pump. The leakage current from all these machines passes through the patient to earth ground, which increases the interference together with line frequency inteference and radio frequency interference.

System Diagram and Main Signal Chain



System Diagram



Main Signal Chain

Notes: The diagram and signal chains above are representative of electrophysiology 3D cardiac mapping systems. The technical requirements of the blocks vary, but the products listed in the table are representative of ADI's solutions that meet some of those requirements.

Market Category

Amplifier	Instrumentation Amplifier	ADC Driver	ADC	DAC	Voltage Reference	Mux/Switch
LTC6240/LTC6241/ LTC6242/ADA4627-1/ LT1819/AD8656	AD8220/AD8221 AD8420/AD8421	ADA4940/ LTC6363	AD7768/ AD4003/ AD7124	AD5541/AD5544/ AD5621/AD5310R	ADR4525/ADR4550/ LTC6655/ADR4530	ADG1634/ ADG5212

Impedance AFE	Isolation	Authentication	Power Module	Switch Regulator	LDO	Sequencer	Protector	Interface
AD5940/ AD5933	ADuM261/ ADuM262/ ADum415x/ MAX2244x/ ADuM2251	DS2505/ DS28E01/ DS2482/ DS18B20	LTM460x/ LTM4622/ LTM8060	LT3002/ LT1617/ LT8643S/ LTC330x	LT3045/ LT3094/ ADM715x/ ADM717x	ADM1185/ MAX16165/ MAX16166	MAX30034	ADM2490E/ ADM3101E/ ADM3075E/ MAX14789E

Introduction of Main Products for Electrophysiology 3D Cardiac Mapping Systems

Part	Description	Benefits
Amplifier		
LTC6240	The LTC6240/LTC241/LTC6242 are single, dual, and quad low noise, low offset, rail-to-rail output, unity-gain stable CMOS op amps that feature 1 pA max of input bias current; the 0.1 Hz to 10 Hz noise of only 550 nV p-p, offset voltage: 125 µV, V_{NOISE} RTI: 10 nV/√Hz at 1 kHz; 18 MHz gain bandwidth, and 10 V/µs slew rate	Low bias current and low noise, wide supply range
AD8656	The AD8655/AD8656 provide low noise (2.7 nV/√Hz at 10 kHz), low THD + N (0.0007%), and high precision performance (250 µV max over VCM) to low voltage applications	Improves the resolution and dynamic range in low voltage applications
ADA4627-1	The ADA4627-1/ADA4637-1 are wide bandwidth precision amplifiers featuring low noise, very low offset voltage and drift, 200 µV maximum, 1 µV/°C typical, and bias current 5 pA maximum; the parts operate from ±5 V to ±15 V dual supply	Low noise, low bias current, JFET op amp
Instrumentation Amplifier		
AD8220	The AD8220 is a single-supply, JFET input instrumentation amplifier available in an MSOP package; designed to meet the needs of high performance, portable instrumentation, the AD8220 has a minimum common-mode rejection ratio (CMRR) of 86 dB at DC and a minimum CMRR of 80 dB at 5 kHz for G = 1; maximum input bias current is 10 pA and typically remains below 300 pA over the entire industrial temperature range; despite the JFET inputs, the AD8220 typically has a noise corner of only 10 Hz	JFET input instrumentation amplifier with rail-to-rail output
AD8221	The AD8221 is a gain programmable, high performance instrumentation amplifier that delivers the industry's highest CMRR over frequency in its class; the CMRR of instrumentation amplifiers on the market today falls off at 200 Hz; in contrast, the AD8221 maintains a minimum CMRR of 80 dB to 10 kHz for all grades at G = 1; high CMRR over frequency allows the AD8221 to reject wideband interference and line harmonics, greatly simplifying filter requirements	Precision instrumentation amplifier
AD8420	The AD8420 is a low cost, micropower, wide supply range, instrumentation amplifier with a rail-to-rail output; minimum CMRR: 100 dB, dual supply: ±2.7 V to ±18 V; bandwidth (G = 100): 2.5 kHz	Wide supply range, rail-to-rail output instrumentation amplifier
AD8421	The AD8421 is a low cost, low power, extremely low noise, ultralow bias current, high speed instrumentation amplifier; 3.2 nV/√Hz maximum input voltage noise at 1 kHz, 200 fA/√Hz current noise at 1 kHz, 94 dB CMRR minimum (G = 1) 500 pA maximum input bias current, 2 MHz bandwidth (G = 100)	Low noise, low bias current, high CMRR for medical instrumentation application
ADC Driver		
ADA4940-1	Fully differential ADC driver, noise RTI: Vn = 3.9 nV/√Hz and In = 0.81 pA/√Hz; 260MHz signal bandwidth	Suitable for ADC driver, low noise for small signal conditioning
LTC6363	The LTC6363 is a fully differential, low power, low noise amplifier with rail-to-rail outputs; noise RTI: Vn = 2.9 nV/√Hz and In = 0.55 pA/√Hz; 500 MHz signal bandwidth	20-bit, 18-bit and 16-bit SAR ADC drivers
ADC		
AD7768	8-channel, 24-bit, simultaneous sampling ADC, power scaling, 110.8 kHz BW, 256 kSPS maximum ADC ODR per channel, 108 dB dynamic range, –120 dB THD, typical	High SNR, low distortion
AD4003	The AD4003/AD4007 are low noise, low power, high speed, 18-bit, 2 MSPS/1 MSPS SAR ADCs; SNR: 100.5 dB typical at 1 kHz, THD: –123 dB typical at 1 kHz	Low power, high SNR, low distortion
AD7124-8/ AD7124-4	8-channe/4-channel, low noise, low power, 24-bit, sigma-delta ADC with PGA and reference; up to 22 noise free bits in all power modes (gain = 1), output data rate: full power: 9.38 SPS to 19.2 kSPS	High precision and low noise suitable for low frequency measurement

Introduction of Main Products for Electrophysiology 3D Cardiac Mapping Systems (Continued)

Part	Description	Benefits
DAC		
AD5541	The AD5541/AD5542 are single, 16-bit, serial input, voltage output digital-to-analog converters, 1 µs settling time, 11.8 nV/√Hz	High resolution and low glitch
AD5621	The AD5601/AD5611/AD5621 are single, 8-bit/10-bit/12-bit, buffered voltage output DACs, on-chip output buffer amplifier, rail-to-rail operation; 1 µs settling time	Low power consumption
AD5310R	The AD5310R/AD5311R are low power, single-channel, 10-bit buffered voltage-out DACs; offset error: ±1.5 mV maximum gain error: ±0.05% of FSR maximum	Low glitch: 0.1 nV, high drive capability and low power
Voltage Reference		
LTC6655	Low drift precision references; low noise: 0.25 ppm (0.1 Hz to 10 Hz) 625 nV p-p; low drift: 2 ppm/°C max, high accuracy: ±0.025% max	High accuracy, low drift, low noise
ADR4525	The ADR4520/ADR4525/ADR4530/ADR4533/ADR4540/ADR4550 devices are high precision, low power, low noise voltage references featuring ±0.02% maximum initial error, maximum temperature coefficient (TCVOUT): 2 ppm/°C	High accuracy, low power, low noise
Mux/Switch		
ADG1634	The ADG1633 and ADG1634 are monolithic industrial CMOS (iCMOS®) analog switches comprising three independently selectable single-pole, double-throw (SPDT) switches and four independently selectable SPDT switches, respectively; 4.5 Ω typical on resistance 1 Ω on-resistance flatness	Very low on resistance
ADG5212	The ADG5212/ADG5213 contain four independent single-pole/single-throw (SPST) switches; latch-up proof, 3 pF off source capacitance, 5 pF off drain capacitance, 0.07 pC charge injection	Ultralow capacitance and charge injection
Impedance AFE		
AD5940	The AD5940/AD5941 are high precision, low power analog front ends (AFEs) designed for portable applications that require high precision, electrochemical-based measurement techniques, such as amperometry, voltametric, or impedance measurements; 16-bit ADC with both 800 kSPS and 1.6 MSPS options, high speed TIA to handle wide bandwidth input signals from 0.015 Hz up to 200 kHz, dual output voltage DAC with an output range of 0.2 V to 2.4 V	Programmable output peak-to-peak excitation voltage, impedance measurement, internal temperature sensor, phase measurement
AD5933	The AD5933 is a high precision impedance converter system solution that combines an on-board frequency generator with a 12-bit, 1 MSPS, ADC; The frequency generator allows an external complex impedance to be excited with a known frequency; The response signal from the impedance is sampled by the on-board ADC and a DFT is processed by an on-board DSP engine	Programmable output peak-to-peak excitation voltage, impedance measurement, internal temperature sensor, phase measurement
Isolation		
ADuM261N	The ADuM260N/ADuM261N/ADuM262N/ADuM263N1 are 5 kV rms 6-channel digital isolators with fail-safe and one reverse channel; 150 Mbps maximum guaranteed data rate	Safety and regulatory approvals: UL/CSA/VDE/CQC
ADuM4151	The ADuM4151/ADuM4152/ADuM4153 are 5 kV rms 7-channel, SPI isolator digital isolators; supports up to 17 MHz SPI clock speed	Safety and regulatory approvals: UL/CSA/VDE
MAX22444	The MAX22444/MAX22445/MAX22446 are 5 kV rms reinforced, fast, low power 4-channel digital galvanic isolators; up to 200 Mbps maximum data rate	Safety and regulatory approvals: UL/CSA/VDE
ADuM2251	The ADuM2250/ADuM2251 are 5 kV rms dual I²C hot swappable digital isolators; 30 mA current sink capability, 1 MHz operation	Safety and regulatory approvals: UL/CSA
Authentication		
DS2505	The DS2505 16 kb add-only memory identifies and stores relevant information about the product to which it is associated; unique, factory-lasered and tested 64-bit registration number (8-bit family code + 48-bit serial number + 8-bit CRC tester)	Provides a guaranteed-unique identity which allows for absolute traceability
DS28E01	The DS28E01-100 is a 1 kb protected 1-Wire® EEPROM with SHA-1 engine; n-chip 512-bit SHA-1 engine to compute 160-bit Message Authentication Codes (MAC)	Provides low-cost, world-class secure authentication
DS2482	The DS2482-800 is an I²C to 1-Wire bridge device that interfaces directly to standard (100 kHz max) or fast (400 kHz max) I²C masters to perform bidirectional protocol conversion between the I²C master and any downstream 1-Wire subnode devices	Support 1-Wire power delivery to 1-Wire devices
DS18B20	The DS18B20 digital thermometer provides 9-bit to 12-bit Celsius temperature measurements and has an alarm function with nonvolatile user-programmable upper and lower trigger points; ±0.5°C accuracy from –10°C to +85°C	High precision temperature monitoring with minimal connections Ideal for multisensor systems
Power Module		
LTM4605	LTM4605 is a high efficiency buck-boost DC-to-DC µModule® (power module) regulator; input voltage range: 4.5 V to 20 V, 0.8 V to 16 V output voltage; 5 A DC typical (12 A DC typical at buck mode)	High efficiency, small size
LTM4622A	Dual ultrathin 2 A or single 4 A step-down DC-to-DC µModule regulator; input voltage range: 3.6 V to 20 V, 1.5 V to 12 V output voltage	Tiny ultrathin, wide input range, fast transient response, stable
LTM8060	Quad 40 V_{IN}, V_{OUT}: 0.8 V to 8 V, 3 A step-down Silent Switcher® µModule regulator, four outputs can be paralleled in an array for up to 12 A capability	Low noise, low EMI

Introduction of Main Products for Electrophysiology 3D Cardiac Mapping Systems (Continued)

Part	Description	Benefits
Switch Regulator		
LT8643S	The LT8640S/LT8643S is 42 V, 6 A synchronous step-down Silent Switcher 2 device with 2.5 µA quiescent current; wide input voltage range: 3.4 V to 42 V, 6 A maximum continuous, 7 A peak output	Silent Switcher 2 technology, ultralow EMI, ultralow noise
LTC3307	The LTC3307 is a 5 V, 3 A, 10 MHz synchronous step-down Silent Switcher device; V_{IN} range: 2.25 V to 5.5 V, V_{OUT} range: 0.5 V to V_{IN}, pin compatible with LTC3308 (4 A) and LTC3309 (6 A)	Silent Switcher technology, ultralow EMI, high efficiency, low noise
LT1617	The LT1617/LT1617-1 are micropower inverting DC-to-DC converters; V_{IN} range: 1 V to 15 V, V_{OUT} up to -34 V, low VCESAT switch: 250 mV at 300 mA	Low quiescent current, small size
LDO		
LT3045	The LT3045 is a high performance low dropout linear regulator with ultralow noise and ultrahigh PSRR; It supplies 500 mA at a typical 260 mV dropout voltage ultralow rms noise: 0.8 µV rms (10 Hz to 100 kHz); ultralow spot noise: 2 nV/√Hz at 10 kHz, ultrahigh PSRR: 76 dB at 1 MHz, V_{IN}: 1.8 V to 20 V	Ultralow noise, ultrahigh PSSR
LT3094	The LT3094 is a high performance low dropout negative linear regulator with ultralow noise and ultrahigh PSRR; it supplies 500 mA at a typical 235 mV dropout voltage ultralow rms noise: 0.8 µV rms (10 Hz to 100 kHz); ultralow spot noise: 2.2 nV/√Hz at 10 kHz, ultrahigh PSRR: 74 dB at 1 MHz, V_{IN}: –1.8 to –20 V	Ultralow noise, ultrahigh PSSR negative LDO
ADM7151	800 mA, ultra low noise/high PSRR adjustable V_{OUT} LDO; Input: 4.5 V to 16 V, output: 1.5 V to 5.1 V, low noise: 1.0 µV rms from 100 Hz to 100 kHz, PSRR of >90 dB from 1 kHz to 100 kHz	Ultralow noise and very high PSRR
ADM7171	6.5 V_{IN}, 1 A, 42 mV dropout LDO, V_{OUT}: 1.2 V to V_{IN} – VDO; low output noise: 5 µV rms (10 Hz to 100 kHz), ADM7172 is 2 A version	Ultralow noise and very high PSRR
Sequencer		
ADM1185	The ADM1185 is an integrated, 4-channel, voltage monitoring and sequencing device; monitors four supplies via 0.8% accurate comparators, three open-drain enable outputs, open-drain power-good output	Monitor and alarm functions for system and power supply sequencing
MAX16165	The MAX16165/MAX16166 monitor up to five voltages and sequence up to four voltages; these devices provide an adjustable delay as each supply is turned on as well as monitor each power-supply voltage, supply range of 2.7 V to 16 V	Monitor and alarm functions for system and power supply sequencing
Protector		
MAX30034	The MAX30034 is a defibrillation/surge/ESD protector intended to absorb repetitive defibrillation and other high energy pulses to protect sensitive electronic circuitry in ECG and other medical/industrial equipment	The devices can withstand over 100k defibrillation pulses without failure
Interface		
ADM2490E	The ADM2490E is a 5 kV signal isolated, high speed (16 Mbps), ESD protected, full-duplex RS-485 transceiver; ±8 kV ESD protection	Safety and regulatory approvals, complies with ANSI TIA/EIA-485-A-1998 and ISO 8482: 1987 (E)
ADM3101E	The ADM3101E is a ±15 kV ESD protected, 3.3 V single-channel RS-232 line driver/receiver, 460 kbps data rate	Meets EIA/TIA-232E specifications
ADM3075E	The ADM3075E is a 3.3 V, ⅛ load, ±15 kV ESD protected, RS-485/RS-422 transceiver (half-duplex, 500 kbps, DE/RE), 500 kbps data rate	Meets TIA/EIA RS-485/RS-422 compliant
MAX14789E	The MAX14784E/MAX14786E/MAX14787E/MAX14789E are full-duplex, ±35 kV ESD-protected, RS-485 transceivers, 500 kbps and 25 Mbps speed options	Robust communication in harsh industrial environments

Design Resources

- Circuits from the Lab®
  - A 16-bit, 6 MSPS SAR ADC system with low power input drivers and reference optimized for multiplexed applications (CN0307)
  - Single-supply, micropower toxic gas detector using an electrochemical sensor (CN0234)
  - High accuracy impedance measurements using 12-bit impedance converters (CN0217)
  - 18-bit, 1.33 MSPS, 16-channel data acquisition system (CN0269)
  - Precision 24-bit, 250 kSPS single-supply sigma-gelta ADC system (CN0310)
- Application Notes/Articles
  - Amperometric/Potentiostat Measurements Using the ADuCM350 (AN-1281)
  - Printed Circuit Board Identification Using 1-Wire Products
  - Optimizing the AD5940 for Electrochemical Measurements (AN-1563)
  - AD594x user guide
  - Fast CMOS Op Amp Challenges Bipolar Amps on All Key Specs

Design Tools/Forums

- ADC/DAC
  - Precision ADC driver tool
  - Precision DAC error budget calculator
  - Virtual eval tool - BETA data converter tools
  - Sigma-Delta ADC Tutorial
- Amplifier and Linear tools
  - ADI precision studio
- Circuit and power design simulation
  - LTspice®: circuit design simulation tool
  - LTpowerCAD and LTpowerPlanner: power supply design tool
  - ADI Power Studio: sequencer design tool

Design Resources

To view additional medical resources, tools, and product information, please visit:

- analog.com/en/applications/markets/healthcare-pavilion-home.html
- maximintegrated.com/en/applications/healthcare.html

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