Technologies for High Performance Portable Healthcare Devices

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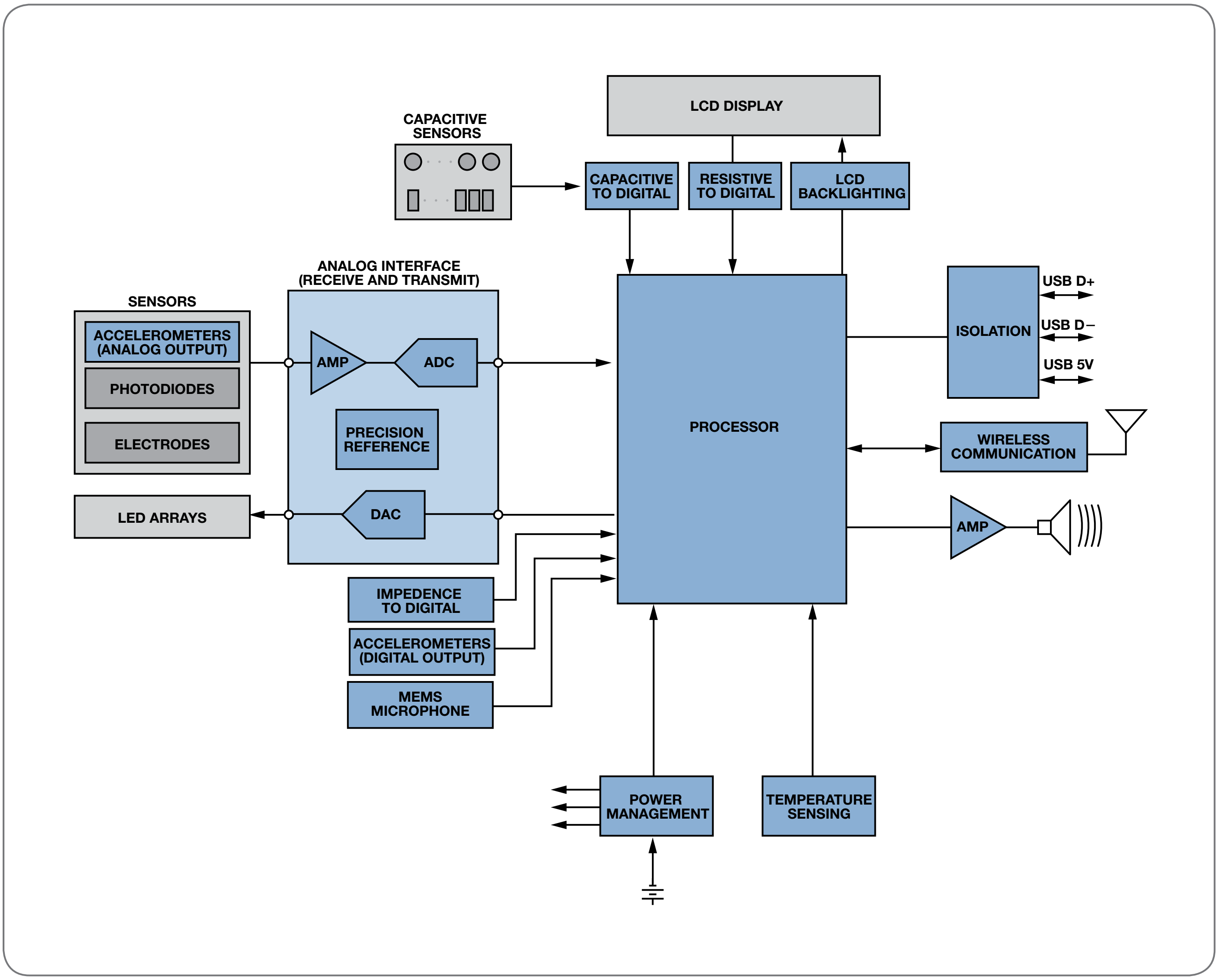
Traditional high performance vital sign monitoring devices and blood analysis instruments currently found in hospitals and clinical laboratories are being redesigned for point-of-care (POC) home use. This market trend is driven by the need to lower the overall cost of healthcare while improving patient diagnosis, care, and comfort.

High performance point-of-care healthcare devices must be designed to address a number of the same requirements as their hospital or clinical counterparts, such as safety from electrical shock, fail-safe features for reliable operation, and user-friendly human interfaces. These devices have additional requirements that impact design, including low power consumption, smaller form factors, measurement sensitivities due to environmental conditions, industry-standard wired or wireless communication, and lower overall system cost.

Portable Home Healthcare Device Functional Block Diagram



Analog Devices offers the following technologies to meet the requirements and challenges of high performance portable home healthcare devices, including vital sign monitors, such as heart rate monitors, eldercare activity monitors, and pedometers; blood analysis/glucose meters; hearing aids; and drug/insulin delivery systems.

- MEMS inertial sensors for motion detection and measurement
- Photocurrent-to-voltage precision amplifiers for photodetection measurement
- High precision impedance-to-digital system for blood coagulation and fluid analysis
- Capacitive sensing for hermetically sealed user interfaces and body worn sensor contact
- Low power, high performance components that interface to electrodes, optical sensors, and inertial sensors
- Low cost, high performance microcontrollers and digital signal processors
- ISM band radio system on a chip (SoC) and transceivers for reliable wireless transfer of data
- *i*Coupler® isolation technology for safety from hazardous line voltages
- High efficiency power management for battery operated devices
- Small, highly accurate temperature sensors

MEMS Inertial Sensors for Motion Detection and Precise Measurement

MEMS inertial sensors can be used in a diverse variety of portable home healthcare and wellness applications. Eldercare activity monitors, fall detection monitors for workers at high risk, and pedometers for exercise enthusiasts rely on low-*g* accelerometers for motion detection, velocity, and positional measurements. Less obvious applications include device operation functions such as automatic wake-up that is triggered with a quick shake or tap of the device.

ADI offers the industry's broadest MEMS-based accelerometer portfolio available in 1-, 2-, and 3-axis configurations, with either analog or digital outputs, in low-*g* sensing ranges. The low power digital output devices are highly programmable to support a number of applications.

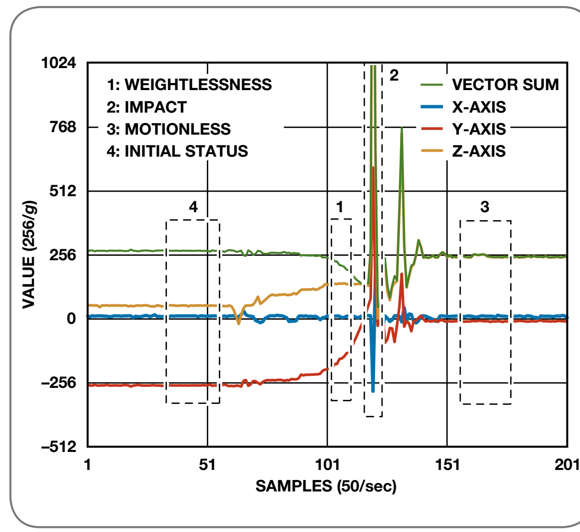
Pedometers

Full-featured pedometers rely on MEMS inertial sensors and software algorithms to reliably detect true steps under many use cases. For example, a user may be walking or running up and down a rough terrain or set of stairs. ADI's MEMS inertial sensors permit more accurate detection of steps and fewer false positives combined with distance, speed, and calories burned. By taking advantage of the low cost, low power, and space requirements of ADI's low-*g* accelerometers, pedometers are being integrated into an increasing number of portable consumer electronic devices—such as MP3 players, mobile phones, and athletic shoes.

Human Fall Detection

Statistics show that the majority of serious consequences from an unobserved fall are not the direct result of falling but rather are due to a delay in assistance and treatment. Post-fall consequences can be greatly reduced if relief personnel can be alerted in time. This is especially the case for the elderly population, however, there are many other conditions and activities for which an immediate alert to a possible fall, especially from substantial height, would be quite helpful—for example, mountaineers, construction workers, window washers, painters, and roofers.

A fall detector based on a 3-axis *i*MEMS® accelerometer detects changes in motion and body position of an individual wearing a sensor by tracking acceleration changes in three orthogonal directions. The data is continuously analyzed algorithmically to determine whether the individual's body is falling or not. If an individual falls, the device can employ GPS and a wireless transmitter to determine their location and issue an alert in order to get assistance. The core element of fall detection is an effective, reliable detection principle and algorithm to judge the existence of an emergency fall situation. Low power consumption is critical for the algorithms and the sensor because the device must be on or "active" at all times.



Acceleration change curves during the process of falling.

Advanced Features: Automatic Wake-Up and Power-Down Modes

ADI MEMS-based digital output accelerometers offer advanced functions for system power savings and quality user experience. The accelerometer can be programmed to automatically wake up the system controller of a device when applying a short rapid shake or two when the device needs to be activated. The host controller can be configured in shutdown mode while waiting for an interrupt from the accelerometer indicating the device has been shaken. Also, the accelerometer can be programmed to shut down the system controller based on a defined and configurable time of no activity (lack of motion or movement).

iMEMS Accelerometers

Part Number	Number of Axes	*g* Range	Sensitivity/*g*	Sensitivity Accuracy (%)	Output Type	BW (kHz)	Noise Density ($\mu g/\sqrt{Hz}$)	Voltage Supply (V)	Supply Current (µA)	Temp Range (°C)	Package
ADXL335	3	±3	300 mV	±10	Analog	1.6	300	1.8 to 3.6	350	–40 to +85	LFCSP
ADXL345	3	±2/±4/±8/±16	Up to 256 LSB	±10	Digital	1.6	220	2.0 to 3.6	40 to 145	–40 to +85	LGA
ADXL346	3	±2/±4/±8/±16	Up to 256 LSB	±10	Digital	1.6	220	1.7 to 2.75	40 to 145	–40 to +85	LGA

High Quality Audio Acquisition Using MEMS Microphones

High performance, low power MEMS microphone technology is ideal for a variety of portable home healthcare applications, including medical alert bracelets, blood pressure monitoring devices, and hearing aids—any device requiring high acoustic performance in a small form factor. ADI MEMS microphones integrate a MEMS sensor and an ASIC, allowing for an increased level of integration in the signal chain. ADI's MEMS microphone portfolio includes traditional analog output as well as various digital output formats such as the increasingly popular pulse density modulation (PDM) output and the ubiquitous I^2S output.

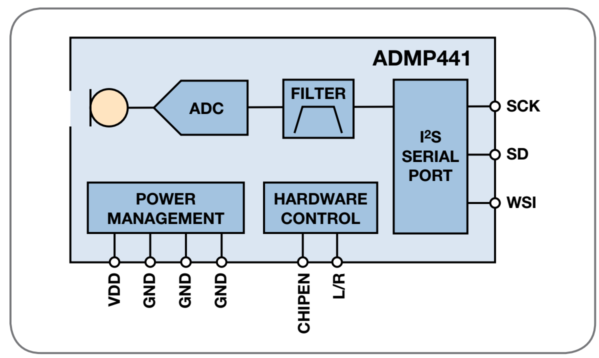
MEMS technology offers greater reliability and design flexibility over traditional electret condenser microphone (ECM) technology. There is no performance degradation over time and less sensitivity to mechanical noise. Stability across temperature and after solder reflow enables the designer to place the microphone or multiple microphones virtually anywhere in a design. MEMS microphones enable functions not previously considered for audio capture due to size and/or performance. Lower power consumption supports an extended battery life.

ADMP441: Low Power, Digital Output, Omnidirectional Microphone with Bottom Port

The ADMP441 high performance MEMS microphone integrates a MEMS sensor, signal conditioning, an analog-to-digital converter (ADC), antialiasing filters, power management, and an industry-standard 24-bit I^2S interface. This level of integration allows the audio output from the device to feed directly into any DSP or microcontroller with an I^2S port. The ADMP441 offers a flat wideband frequency response resulting in a highly intelligible, natural sound. A built-in particle filter provides high reliability. The ADMP441 has a high SNR and a high sensitivity, making it an excellent choice for far field applications.

ADMP441 Features

- Digital I^2S interface with high precision 24-bit data
- High SNR: 61 dBA
- High sensitivity: –26 dBFS
- Flat frequency response: 100 Hz to 15 kHz
- Low current consumption: <1.5 mA
- High PSRR: 80 dBFS
- Package: 4.72 mm × 3.76 mm × 1.00 mm surface-mount



High Performance MEMS Microphones

Part Number	Output Type	Signal-to-Noise Ratio, SNR (dB)	Min Equivalent Input Noise, EIN (dB)	Frequency Response Range	Sensitivity @ 1 kHz	Package Type	Package Size (mm)
ADMP401	Analog	62	32	100 Hz to 15 KHz	–42 dBV	LGA	4.72 × 3.76 × 1
ADMP404	Analog	62	32	100 Hz to 15 KHz	–38 dBV	LGA	3.35 × 2.5 × 0.88
ADMP405	Analog	62	32	200 Hz to 15 KHz	–38 dBV	LGA	3.35 × 2.5 × 0.88
ADMP421	Digital (PDM)	61	33	100 Hz to 15 KHz	–26 dBFS	LGA	3 × 4 × 1
ADMP441	Digital (I^2S)	61	33	100 Hz to 15 KHz	–26 dBFS	LGA	4.72 × 3.76 × 1

Photocurrent-to-Voltage Amplifiers for Photodetection Measurement

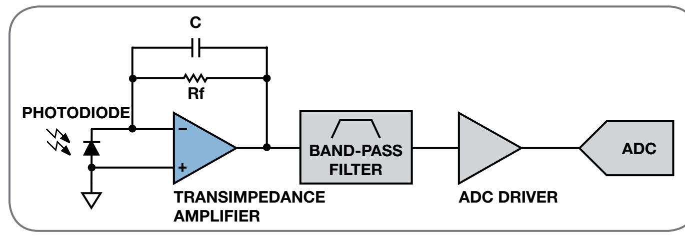
Photodetectors are commonly used in point-of-care healthcare devices, including pulse oximeters (SPO2) to measure heart rate and blood oxygen level, blood glucose test meters, flow cytometers to measure microscopic particles, and body fluid analyzers. An LED or multiple LEDs of selected wavelengths are generally pulsed through the object (for example, body tissue or fluid) while the photodetector measures the resultant transmissive or reflective signal that is proportional to the desired measurement. In all cases, the photocurrent from the photodetector is very small. Nanoamp magnitudes are not uncommon.

A transimpedance amplifier (TIA) with a large value feedback resistor is most often used to convert the photocurrent to a voltage. Since the photocurrent is very small, it can get buried in noise, and careful attention must be given to system noise sources and operational amplifier selection.

When selecting an op amp for measuring a very small photocurrent in a TIA configuration, choose:

- Very low input bias current to prevent the op amp from bleeding off the photodetector current signal
- Low voltage and current noise to prevent adding additional noise
- Low offset voltage to prevent dark current from being generated in the photodetector

The op amp voltage supplies will depend on how much dynamic range is required.



Typical LED + photodetector system.

Operational Amplifiers for Photocurrent Detection Measurement

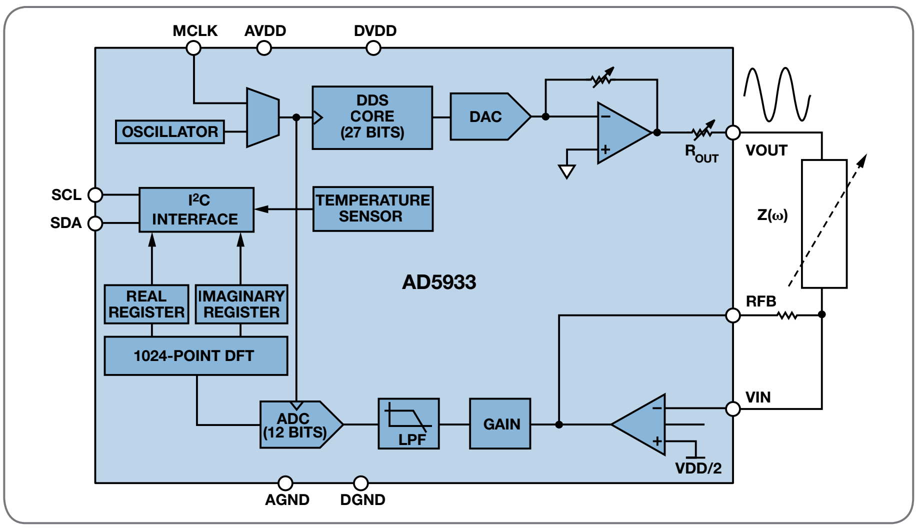
Amplifier	Voltage Noise (nV/√Hz) @ 1 kHz	Current Noise (fA/√Hz) @ 1 kHz	Offset Voltage (V_{os}/mV)	Input Bias Current (pA)	GBWP	Supply Voltage (V)	Supply Current (Per Channel)	Package
AD8505	45	15	0.5	1	95 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	16.5 µA	WLCSP
AD8506	45	15	0.5	1	95 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	16.5 µA	MSOP, WLCSP
AD8508	45	15	0.5	1	95 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	16.5 µA	TSSOP, WLCSP
ADA4691	16	N/A	0.5	0.5	3.6 MHz	Single: 2.7 to 5 Dual:±1.35 to ±2.5	180 µA	LFCSP, WCCSP
ADA4528	5.6	0.7	0.3 µV	220	4 MHz	Single: 2.2 to 5 Dual: ±1.10 to ±2.75	1.4 mA	MSOP
AD8657	60	0.1	0.35	1	200 kHz	Single: 2.7 to 18.0 Dual: ±1.35 to ±9.0	18 µA	MSOP, LFCSP
AD8641	29	0.5	0.05	1	3.5 MHz	Single: 5 to 26 Dual: ±2.5 to ±13	195 µA	MSOP, SOIC, LFCSP
AD8625	17	0.4	0.05	1	5 MHz	Single: 5 to 26 Dual: ±2.5 to ±13	630 µA	SOIC, TSSOP
AD8626	17	0.4	0.05	1	5 MHz	Single: 5 to 26 Dual: ±2.5 to ±13	630 µA	SOIC, MSOP
AD8627	17	0.4	0.05	1	5 MHz	Single: 5 to 26 Dual: ±2.5 to ±13	630 µA	SOIC, SC70
AD8665	10	N/A	0.7	1	4 MHz	Single: 5 to 16 Dual:±2.5 to ±8	1.1 mA	SOT-23, SOIC
AD8666	10	N/A	0.7	1	4 MHz	Single: 5 to 16 Dual:±2.5 to ±8	1.1 mA	SOIC, MSOP
AD8668	10	N/A	0.7	1	4 MHz	Single: 5 to 16 Dual:±2.5 to ±8	1.1 mA	TSSOP, SOIC
AD8605	8	0.01	0.08	1	10 MHz	Single: 2.7 to 5.5	1.0 mA	SOT-23, WLCSP
AD8606	8	0.01	0.08	1	10 MHz	Single: 2.7 to 5.5	1.0 mA	MSOP, WLCSP
AD8608	8	0.01	0.08	1	10 MHz	Single: 2.7 to 5.5	1.0 mA	SOIC, TSSOP
ADA4505-1	65	20	0.5	0.5	50 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	10.0 µA	WLCSP, SOT-23
ADA4505-2	65	20	0.5	0.5	50 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	10.0 µA	WLCSP, MSOP
ADA4505-4	65	20	0.5	0.5	50 kHz	Single: 1.8 to 5 Dual: ±0.9 to ±2.5	10.0 µA	WLCSP, TSSOP

High Precision Impedance-to-Digital Converter for Blood Coagulation and Fluid Analysis

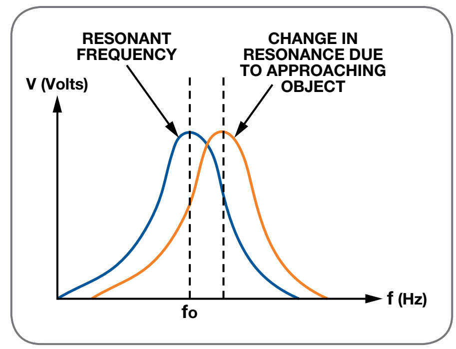
Blood coagulation is a complex, dynamic physiological process by which clots are formed to end bleeding at an injured site. Blood coagulation in the body is modulated by a number of cellular and other active components. The coagulation cascade describes the components of blood and how they are involved in the process of clot formation. As the cascade becomes activated, the blood progresses from a nonclotting to a clotting state, causing changes in both molecular charge states and effective charge mobility. By monitoring the global impedance of a clotting blood sample, the changes in conductivity associated with clot formation are measured.

Fully Integrated, Single-Chip Impedance Converter Analyzer

The AD5933 is a high precision impedance converter analyzer that combines an on-board frequency generator with a 12-bit, 1 MSPS, analog-to-digital converter (ADC). The frequency generator provides an excitation voltage to an external complex impedance at a known frequency. The response signal (current) is sampled by the on-board ADC, and a discrete Fourier transform (DFT) is processed by an on-board DSP engine. The DFT algorithm returns real (R) and imaginary (I) data words at each output frequency. The magnitude and relative phase of the impedance at each frequency point along the sweep can be easily calculated.



The AD5933 block diagram illustrates the advanced level of integration contained in its single-chip form factor.



Special plot created by sweeping sample with different frequencies.

Impedance-to-Digital Converters

Part Number	Master fclk (MHz)	Resolution	Tuning Word Width	I/O Interface	Impedance Measurement Range	Internal Temperature Sensor (°C)	I Supply Total Max (mA)	Nominal Supply (V)	Package
AD5933	16.776	12-bit (1 MSPS)	27 bits	Serial	1 kΩ to MΩ	±2	15	Single (+5)	16-lead SSOP
AD5934	16.776	12-bit (250 kSPS)	27 bits	Serial	1 kΩ to MΩ	—	1	Single (+2.7), Single (+5)	16-lead SSOP

Capacitive Sensing for Hermetically Sealed User Interfaces and Body Worn Sensor Contact

The human interface must also support a wide range of individuals with varied intellectual and physical capacities including eyesight, manual dexterity, and hearing. The interface also must offer smart, closed-loop, fail-safe features that will ensure proper, reliable, and safe device operation under all conditions.

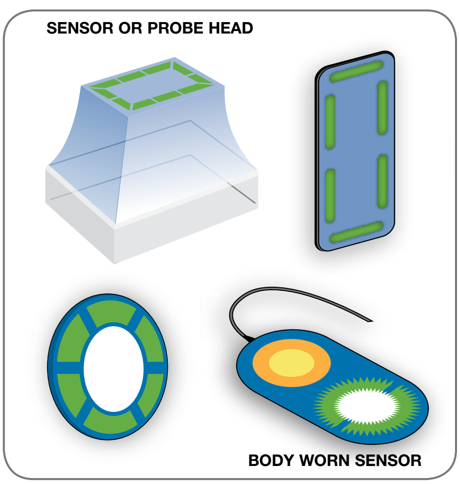
Capacitive sensing is an ideal solution for developing a complete hermetically sealed device that is secure against the entry of water vapor and foreign bodies in order to maintain proper function levels and reliability under all conditions. Furthermore, a sealed capacitive sensing human interface eliminates the traditional mechanical buttons that are prone to collecting bacteria or subject to harsh cleaning liquids. Additional benefits of replacing traditional mechanical buttons with capacitive sensing include eliminating the mechanical buttons from the bill of materials and easier product assembly during product manufacturing.

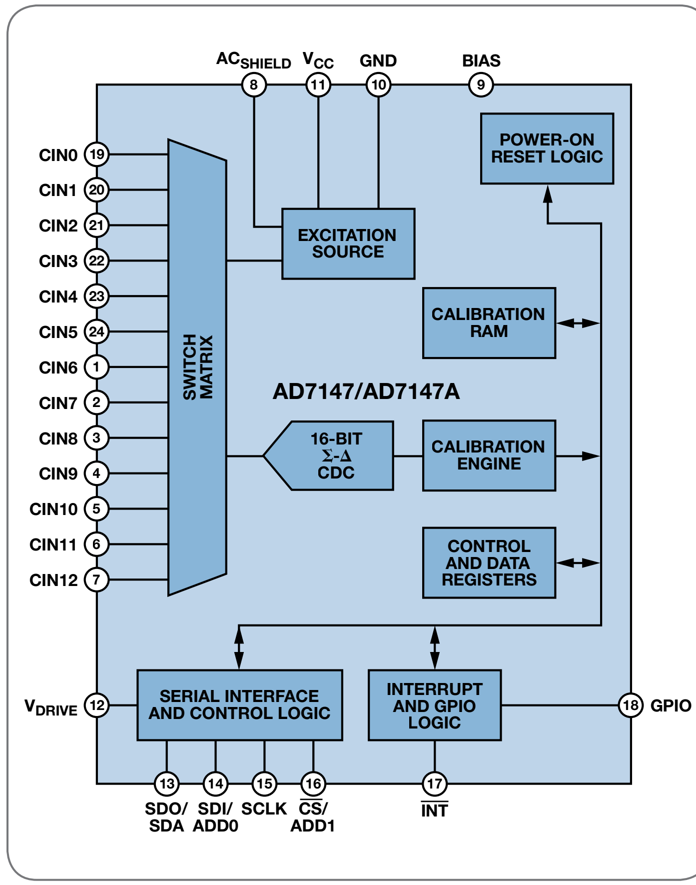
It is often beneficial to have information about the quality of contact between the device's surface area and the skin before the device is activated or a measurement is taken. The range of devices could include a medical probe that needs to rest flush on the skin, a biopotential electrode sensor, or the housing holding a catheter tube in place. To achieve this additional performance, several capacitive sensor electrodes, shown in green, could be embedded directly into the device's plastic housing at the injection molding stage during manufacturing. Once the electrode information is available, a simple algorithm running on the host controller can be applied to determine if all sensor electrodes are making proper contact with the skin.

Selecting a Capacitive Sensor Controller

Selecting a capacitive sensor controller should start by selecting a controller that:

- Does not require external RC sensor tuning components.
- Includes an analog front end (AFE) that supports accurate measurements to detect the small energy on the capacitive sensors.
- Offers on-chip environmental tracking and calibration to correct for environmental baseline drift errors.
- Includes on-chip parasitic capacitance offset adjustment and low latency periods from touch to response.





Capacitive-to-Digital Controllers (CDCs)

Part Number	Resolution (Bits)	Rate (ms)	Number of Channels	Supply Voltage (V)	Power Dissipation	Input Base C (pF Max)	C_{IN} Range (pF)	Package
AD7148	16	9	8	Multi (+3.3 analog, +3.3 digital)	3.3 mW = full power 71 µW = low power	20	±8	LFCSP
AD7147A	16	9	13	Single (+3), Single (+3.3)	3.3 mW = full power 71 µW = low power	20	±8	LFCSP
AD7147	16	9	13	Single (+3), Single (+3.3)	3.3 mW = full power 71 µW = low power	20	±8	WLCSP
AD7156	12	10	2	1.8 to 3.6	0.25 mW = full power 0.7 µW = shut down (3.6 V supplies)	12.5	0.0 to 4.0	LFCSP

Low Power, High Performance Analog Interface

For designs that interface to electrodes, photodiodes, or analog output sensors, Analog Devices offers the industry's broadest portfolio of low power, high performance operational amplifiers (op amps), analog-to-digital converters (ADCs), and digital-to-analog converters (DACs.) For designs requiring a higher level of integration, ADI offers a variety of application-specific standard products (ASSPs) and ASIC solutions. Contact your ADI sales representative for more information.

Low Power, Precision Amplifiers

High performance amplifiers provide the critical analog interface between the device and external sensors (electrodes, photodiodes, chemical assays, etc.). In portable battery-powered applications, these amplifiers must support a lower power budget and small footprint without sacrificing the performance found in higher power, clinical-level devices.

The types of amplifiers and specifications required vary depending on the sensor used and the end device. Below are a few guidelines:

- ECG and EEG applications including heart rate monitors: instrumentation amplifiers with a high common-mode rejection ratio; high performance operational amplifiers for the gain and filter stages employed in the device.
- Photodiode applications including glucose meters (amperometric and photometric): traditional operational amplifiers as buffers; low noise, low input bias current, and low offset voltage amplifiers.
- Blood pressure applications: low power, high precision instrumentation amplifiers for the bridge sensor application.

Instrumentation Amplifiers

Part Number	Description	Supply	V_{CC} to V_{EE} (V)	Supply Current	Gain Setting Method	Bandwidth G = 10 Typ (kHz)	Gain Min	Gain Max	Min CMRR @ 60 Hz Min Gain (dB)	Min CMRR @ 60 Hz Max Gain (dB)	V_{NOISE} RTI 1 Hz to 10 Hz (µV p-p)
AD8220	R-R JFET	Single/dual	4.6 to 36	750 µA	Resistor	800	1	1000	78	94	0.8
AD8223	Single supply R-R	Single/dual	3 to 25	0.6 mA	Pin	200	5	1000	70	105	2
AD8226	Wide supply R-R	Single/dual	2.2 to 36	350 µA	Resistor	160	1	1000	80	105	2
AD8235	Small, low power	Single	1.8 to 5.5	40 µA	Resistor	8.8	5	200	60	60	5
AD8236	Ultralow power, RRIO	Single	1.8 to 5.5	40 µA	Resistor	8.8	5	200	60	60	5
AD627	Micropower	Single/dual	2.2 to 36	0.06 mA	Resistor	30	5	1000	77	77	1.2

Operational Amplifiers

Part Number	Process	Number of Amps	Supply Voltage Min/ Max (V)	I_S/ Amp Max (mA)	Rail-to-Rail	BW @ A_{CL} Min (MHz)	Slew Rate (V/µs)	V_{OS} Max (mV)	TcV_{OS} Typ (µV/°C)	CMRR Min (dB)	PSRR Min (dB)	A_{VO} Min (dB)	Noise @ 1 kHz (nV/√Hz)	I_B Max (pA)	Package
AD8500	CMOS	1	1.8/5.5	0.001	RRIO	0.007	0.004	1	3	75	90	98	190	10	SC70
AD8502 AD8504	CMOS	2 4	1.8/5.5	0.001	RRIO	0.007	0.004	3	5	67	85	98	190	10	SOT-23 TSSOP
ADA4505-1 ADA4505-2 ADA4505-4	CMOS	1 2 4	1.8/5.5	0.010	RRIO	0.050	0.006	3	2	90	100	105	65	2	WLCSP/SOT-23 WLCSP/MSOP WLCSP/TSSOP
AD8505 AD8506 AD8508	CMOS	1 2 4	1.8/5.5	0.020	RRIO	0.095	0.013	2.5	2	90	100	105	45	10	WLCSP/SOT-23 WLCSP/MSOP WLCSP/TSSOP
AD8603 AD8607 AD8609	CMOS	1 2 4	1.8/6	0.040	RRIO	0.4	0.1	0.3	1	85	80	112	25	1	SOT-23 MSOP/SOIC SOIC/TSSOP
AD8613 AD8617 AD8619	CMOS	1 2 4	1.8/5.5	0.040	RRIO	0.4	0.1	2.2	1	68	67	107	25	1	SC70/SOT-23 MSOP/SOIC SOIC/TSSOP
AD8541 AD8542 AD8544	CMOS	1 2 4	2.7/6	0.045	RRIO	1	0.92	6	4	40	65	86	40	60	SC70/SOT-23/SOIC MSOP/SOIC/TSSOP SOIC/TSSOP
AD8538 AD8539	CMOS	2 4	2.7/5.5	0.180	RRIO	0.43	0.35	0.013	0.03	115	105	115	50	25	SOT-23/SOIC MSOP/SOIC
ADA4092-4	Bipolar	4	±1.35/ ±18	0.250	RRIO	1.4	0.4	1.5	2.5	90	98	116	30	60	TSSOP
AD8641 AD8642 AD8643	JFET	1 2 4	±2.5/ ±13	0.290	SS	3.5	3	0.75	2.5	90	90	106	27.5	1	SC70/SOIC MSOP/SOIC SOIC/LFCSP

Low Power, High Performance Analog Interface (Continued)

In addition to some of the amplifiers listed in the table, designers can select op amps by parameters, find expert system-level advice on design problems with our amplifier reference circuits (Circuits from the Lab™), and download design tools, selection guides, calculators, and SPICE models at *www.analog.com/amplifiers*.

Data Converters

As the world's leading provider of data converters, Analog Devices offers digital-to-analog and analog-to-digital converters from 8 bits to 24 bits. ADI converters are unmatched in their ability to deliver performance and value, and they are supported by design tools and technical documentation engineers need to accelerate time to market. Whether the data conversion challenge is high speed or precision, engineers will find an ADC or DAC to suit every specification: accuracy, resolution, sample rate, bandwidth, power, size, and value.

Low Voltage Precision Digital-to-Analog Converters (DACs)

Part Number	Channels	Bits	On-Chip Reference (V)	Interface	Package
AD5320	1	12	No	SPI	SOT-23, MSOP
AD5621	1	12	No	SPI	SC70
AD5622	1	12	No	I^2C	SC70
AD5620	1	12	1.25/2.5	SPI	SOT-23, MSOP
AD5640	1	14	1.25/2.5	SPI	SOT-23, MSOP
AD5660	1	16	1.25/2.5	SPI	SOT-23, MSOP
AD5322	2	12	No	SPI	MSOP
AD5623R	2	12	1.25/2.5	SPI	LFCSP, MSOP
AD5627R	2	12	1.25/2.5	I^2C	LFCSP, MSOP
AD5643R	2	14	1.25/2.5	SPI	MSOP
AD5663R	2	16	1.25/2.5	SPI	LFCSP, MSOP
AD5324	4	12	No	SPI	LFCSP, MSOP
AD5624R	4	12	1.25/2.5	SPI	LFCSP, MSOP
AD5625R	4	12	1.25/2.5	I^2C	LFCSP, TSSOP
AD5644R	4	14	1.25/2.5	SPI	LFCSP, MSOP
AD5664R	4	16	1.25/2.5	SPI	LFCSP, MSOP

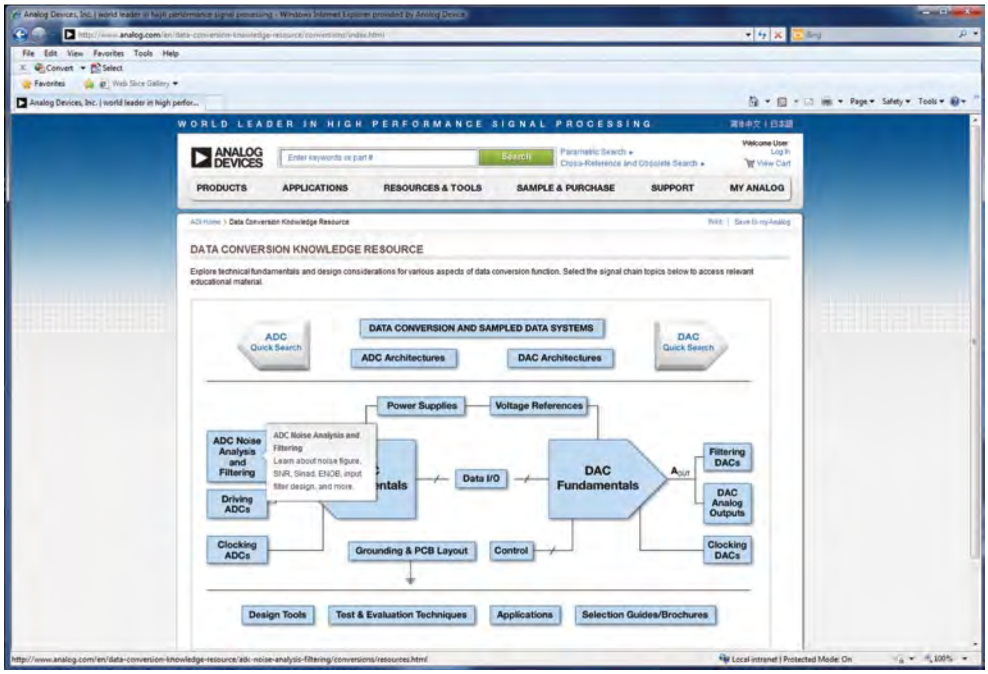
Analog-to-Digital Converters (ADCs)

Part Number	Resolution (Bits)	Channels	INL (Typ)	THD (dB)	Throughput	Supply (V)	Power Dissipation	Package
AD7298	12	8	±0.5 LSB	–82 @ 50 kHz	1 MSPS	Analog: 2.8 to 3.6 Digital: 1.65 to 3.6	17.4 mW	LFCSP (QFN)
AD7476A	12	1	±0.75 LSB	–80 @ 100 kHz	1 MSPS	Analog: 2.35 to 5.25 Digital: 2.35 to 5.25	3.6 mW	SC70, MSOP
AD7476	12	1	±0.6 LSB	–80 @ 100 kHz	1 MSPS	Analog: 2.35 to 5.25 Digital: 2.35 to 5.25	3.6 mW	SOT-23
AD7942	14	1	±0.4 LSB	–100 @ 20 kHz	250 kSPS	Analog: 2.3 to 5.5 Digital: 1.8 to 5.0	1.25 mW @ 2.5 V/100 kSPS 3.6 mW @ 5 V/100 kSPS 1.25 µW @ 2.5 V/100 SPS	MSOP, QFN (LFCSP)
AD7171	16	1	±0.4 LSB	N/A	125 Hz	2.7 to 5.25	0.33 mW	LFCSP
AD7980	16	1	±0.6 LSB	–110 @ 10 kHz	1 MSPS	Analog: 2.5 to 5.0 Digital: 1.8 to 5.0	7.0 mW @ 1 MSPS 70 µW @ 10 kSPS	MSOP, QFN (LFCSP)
AD7685	16	1	±0.6 LSB	–110 @ 20 kHz	250 kSPS	Analog: 2.3 to 5.5 Digital: 1.8 to 5.0	1.4 µW @ 2.5 V/100 SPS 1.35 mW @ 2.5 V/100 kSPS 4 mW @ 5 V/100 kSPS	MSOP, QFN (LFCSP)
AD7682/ AD7689	16	4/8	±0.4 LSB	–100 @ 20 kHz	250 kSPS	Analog: 2.3 to 5.5 Digital: 1.8 to 5.5	3.5 mW @ 2.5 V/200 kSPS 12.5 mW @ 5 V/250 kSPS	LFCSP
AD7986	18	1	±0.6 LSB	–115 @ 20 kHz	2 MSPS (TURBO = high), 1.5 MSPS (TURBO = low)	Analog: 2.3 to 2.6 Digital: 1.8 to 2.7	15 mW @ 2 MSPS, with external reference 26 mW @ 2 MSPS, with internal reference	QFN (LFCSP)
AD7767	24	1	±3 ppm	–115 @ 1 kHz	32 kSPS 64 kSPS 128 kSPS	Analog: 2.3 to 2.6 Digital: 1.8 to 3.6	8.5 mW @ 32 kSPS (AD7767-2) 10.5 mW @ 64 kSPS (AD7767-1) 15 mW @ 128 kSPS (AD7767)	TSSOP

Low Power, High Performance Analog Interface (Continued)

Data Conversion Knowledge Resource

Analog Devices' Data Conversion Knowledge Resource is an easy-to-navigate library of in-depth technical material focusing on key aspects of conversion stage design. Clicking on the individual blocks within the Data Conversion Knowledge Resource home page diagram serves up design and applications engineering content relevant to that specific subject.



Put ADI's 45 year span of pioneering work in data conversion to work for you. Visit the Data Conversion Knowledge Resource for design-relevant handbooks, applications notes, tutorials, webcasts, tools, and more at *www.analog.com/theKnowledgeResource*.

Voltage References

ADI's precision micropower voltage reference products provide class-leading specification in an affordable budget. These parts feature ≤±0.1% initial accuracy, low operating current, and low output noise in small packages, ideal for battery-operated portable devices.

Precision Voltage References

Part Number	Output Voltage (V)	Initial Accuracy (%)	Operating Current	Tempco (ppm/°C)	0.1 Hz to 10 Hz Noise (μV p-p)	Package
ADR3425	2.5	0.1	100 μA max	8	18	SOT-23
AD1580	1.225	0.08, 0.8	50 μA to 10 mA	50, 100	5	SC70/SOT-23
ADR5043	3	0.1, 0.2	50 μA to 15 mA	75, 100	25.8	SC70/SOT-23

Small, Highly Accurate Temperature Sensing

ADI's high performance digital temperature sensors measure temperature to an accuracy of ±0.25°C over a range of –20°C to +105°C and ±0.5°C from –40°C to +125°C. These devices offer breakthrough accuracy and a high level of integration offering designers an alternative to thermistors and the peripheral parts these devices require. There is no extra signal processing, characterization, or calibration required. The sensors offer stable and reliable temperature measurement with a typical drift specification of ±0.0072°C and repeatability of ±0.015°C

Digital Temperature Sensors

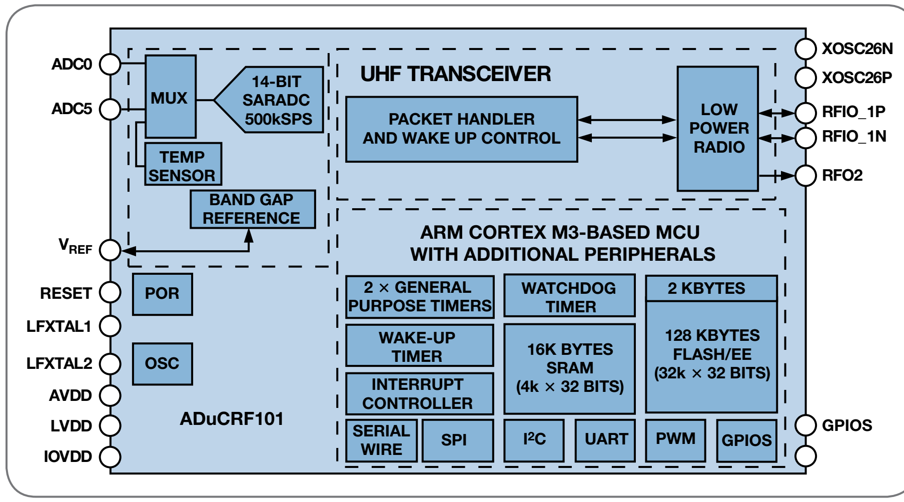
Part Number	Temperature Resolution (°C/LSB)	25°C Temperature Error (°C)	Resolution (Bits)	Serial Interface	Temperature Range (°C)	Supply Voltage Range (V)	Package
ADT7310	0.0078°C	0.5	16	SPI	–55 to +150	+2.7 to +5.5	SOIC
ADT7320	0.0078°C	0.0017	16	SPI	–40 to +150	+2.7 to +5.5	LFCSP
ADT7410	0.0078°C	0.5	16	I²C	–55 to +150	+2.7 to +5.5	SOIC
ADT7420	0.0078°C	0.2	16	I²C	–40 to +150	+2.7 to +5.5	LFCSP

Low Power, Low Cost Precision Analog Microcontrollers and Digital Signal Processors

Analog Devices has an extensive portfolio of digital signal processors (DSPs) and analog microcontrollers for portable home healthcare device design requirements.

Precision Analog Microcontroller: ARM Cortex-M3 with ISM Band Transceiver

For those portable home healthcare designs requiring a high level of integration, the ADuCRF101 system on a chip (SoC) integrates high performance converter technology, an ARM Cortex-M3 processor, on-chip memory, and the added functionality of an RF transceiver for wireless communications on a single chip. It offers low operating power (190 µA/MHz) and can power down to under 1.6 µA with a state retained, making it ideal for mains and battery operated medical devices, including infusion pumps and vital sign monitors.



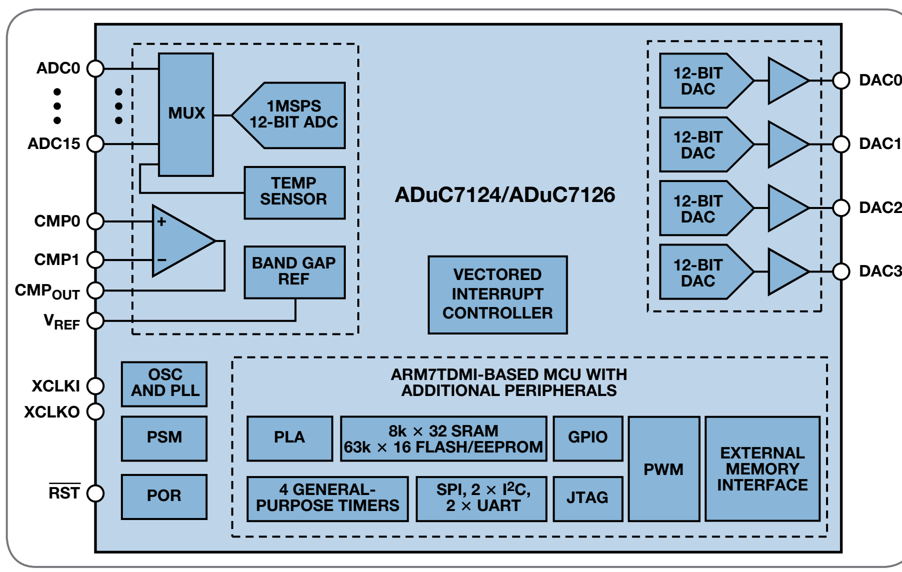
ADuCRF101 functional block diagram.

ADuCRF101 Features

- High performance ISM band RF transceiver
- ARM Cortex-M3 32-bit RISC MCU, 128 kB Flash/EE memory, 16 kB RAM
- Operates directly from 3.6 V battery
- 6-channel, 14-bit, 500 kSPS SAR ADC
- 9 mm × 9 mm, 64-lead LFCSP

Precision Analog Microcontrollers with 12-Bit ARM7TDMI MCU

Analog Devices precision analog microcontrollers combine precision analog functions, such as high resolution ADCs and DACs, voltage reference, temperature sensor, and a host of other peripherals, with an industry-standard microcontroller and flash memory. The ADuC712x ARM7TDMI® family integrates 12-bit ADCs, 12-bit DACs, flash, SRAM, and a host of digital peripherals designed for medical applications.



ADuC7124 functional block diagram.

Precision Analog Microcontrollers

Part Number	MCU Core	MCU Speed (MIPS)	Flash (kB)	SRAM (kB)	GPIO Pins	Resolution (Bits)	ADC Speed (kSPS)	ADC Channels	Other	12-Bit DAC Outputs
ADuC7021	ARM7TDMI	40	62	8	13	12	1000	8	—	2
ADuC7022	ARM7TDMI	40	62	8	13	12	1000	10	—	—
ADuC7024	ARM7TDMI	40	62	8	30	12	1000	10	PWM	2
ADuC7025	ARM7TDMI	40	62	8	30	12	1000	12	PWM	—
ADuC7026	ARM7TDMI	40	62	8	40	12	1000	12	PWM	4
ADuC7027	ARM7TDMI	40	62	8	40	12	1000	16	PWM	—
ADuC7028	ARM7TDMI	40	62	8	40	12	1000	8	—	4
ADuC7124	ARM7TDMI	40	128	32	40	12	1000	16	PWM	4
ADuCRF101	Cortex-M3	20	128	16	28	14	500	6	PWM, radio, DMA	—

Digital Signal Processors

The ADSP-BF52x and ADSP-BF592 Blackfin® processors deliver the computational power required for fast, accurate results for in-home medical systems, including wearable monitoring devices and portable diagnostic systems. In addition to providing the signal processing for real-time analysis, Blackfin processors can provide control of the user interface (LCD, button, touch screen). A range of connectivity options (network wired/wireless, USB) are available to enable the transfer of data from device to patient and doctor.

Reliable Wireless Communication for Transfer of Data

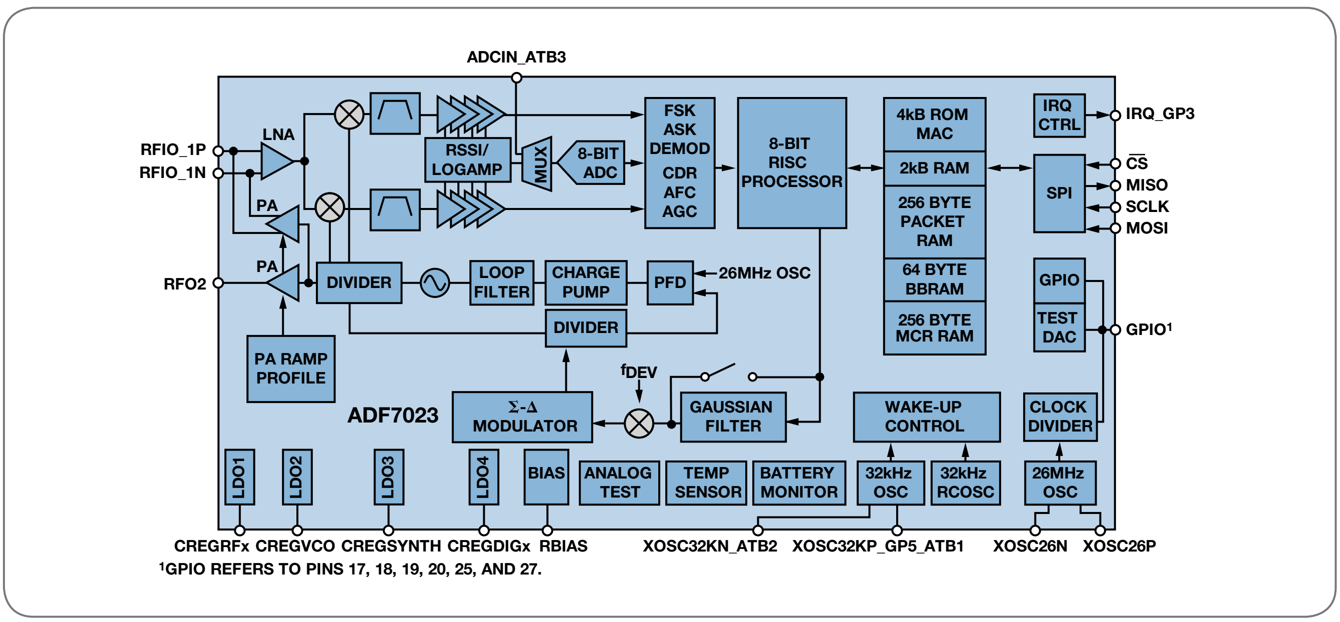
To maximize patient comfort and mobility, wireless connectivity is becoming ubiquitous. Open standards such as Bluetooth and Zigbee provide low cost options for those applications with multiple band requirements, including the 2.4 GHz band. For near-body or body worn sensors, the sub-1 GHz ISM band offers an alternative and can provide maximum design flexibility, including the ability to trade off range against power, optimize data security, and minimize software and memory overhead. To address applications utilizing ISM bands, ADI offers standalone transceivers, as well as a fully integrated system on a chip (SoC) solution.

Low Power ISM Band Transceivers

The ADF7023 is a low power, high performance, highly integrated 2FSK/GFSK/OOK/MSK/GMSK transceiver designed for operation in the 862 MHz to 928 MHz and 431 MHz to 464 MHz frequency bands, which cover the worldwide license-free ISM bands at 433 MHz, 868 MHz, and 915 MHz. It is suitable for circuit applications that operate under the European ETSI EN 300-220, the North American FCC (Part 15), the Chinese short-range wireless regulatory standards, or other similar regional standards. Data rates from 1 kbps to 300 kbps are supported.

ADF7023 Features

- Frequency bands
  - 862 MHz to 928 MHz
  - 431 MHz to 464 MHz
- Data rates supported: 1 kbps to 300 kbps
- 1.8 V to 3.6 V power supply
- Single-ended and differential PAs
- Low IF receiver with programmable IF bandwidths: 100 kHz, 150 kHz, 200 kHz, 300 kHz



ADF7023 functional block diagram.

ISM Band Transceiver with Microcontroller System on a Chip (SoC)

The ADuCRF101 is a fully integrated SoC solution that includes an energy efficient 431 MHz to 464 MHz and 862 MHz to 928 MHz internal UHF transceiver, low power ARM Cortex-M3 core, and Flash/EE memory. The transceiver consumes only 12.8 mA in receive mode, while maintaining a typical sensitivity of –107.5 dB at 38.4 kbps (2FSK). The transmit mode is equally efficient, with supply current as low as 9 mA, depending on the user programmed RF power level. The device operates directly from a 3.6 V battery and utilizes an autonomous packet handler to minimize system current consumption during wireless communications.

RF Transceivers

Part Number	Frequency Range (MHz)	Modulation Mode	Max Data Rate	Phase Noise Floor (dBc/Hz)	Tx Current for 0 dBm (mA)	Rx Current (mA)	Rx Sensitivity (dBm)	Min Pos Supply (V)	Max Pos Supply (V)	Output Power (dBm)	Package
ADF7023	431 to 464, 862 to 928	GFSK/FSK/MSK, GMSK, OOK	300 kbps	196	13	12.8	116	1.8	3.6	–16 to +13.5	32-lead LFCSP
ADF7242	2400 to 2483.5	DSSS-OQPSK, FSK/GFSK	2 Mbps	145	19.6	19	—	1.8	3.6	–20 to +4.8	32-lead LFCSP
ADuCRF101	431 to 464, 862 to 928	GFSK/FSK/MSK, GMSK, OOK	300 kbps	196	13	12.8	116	1.8	3.6	–16 to +13.5	64-lead LFCSP

*i*Coupler Digital Isolator Technology for Safety from Hazardous Line Voltages

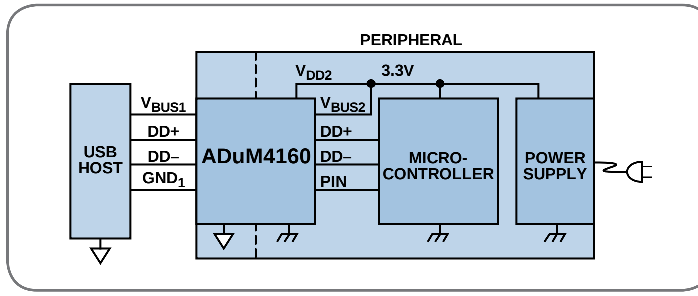
Portable point-of-care medical devices are using the PC USB port to upload data and in some cases to also recharge Li-Ion batteries. Since the PC is also connected to the main ac power lines, it is not uncommon to provide some extra safety precaution by either disabling the device from being used when connected to the USB port or to include electrical isolation between the USB port and the user.

ADuM4160: Full/Low Speed 5 kV rms USB Digital Isolator

The ADuM4160 offers 5 kV rms isolation that is ideal as an alternative to optocouplers for medical applications (IEC 60601-1 medical safety approval). The isolation provided by the ADuM4160 will electrically isolate patients and equipment protecting them from harmful surges or spikes. The isolation also eliminates the need to disconnect during defibrillation.

ADuM4160 Features

- Reinforced isolation for medical applications per IEC 60601-1
- 5 kV rms isolation rating (1 minute) per UL 1577
- Class 3 contact ESD performance per ANSI/ESD STM5.1-2007
- High common-mode transient immunity (>25 kV/µs)
- Direct isolation of USB D+/D– data lines supporting USB low speed and full speed data rates



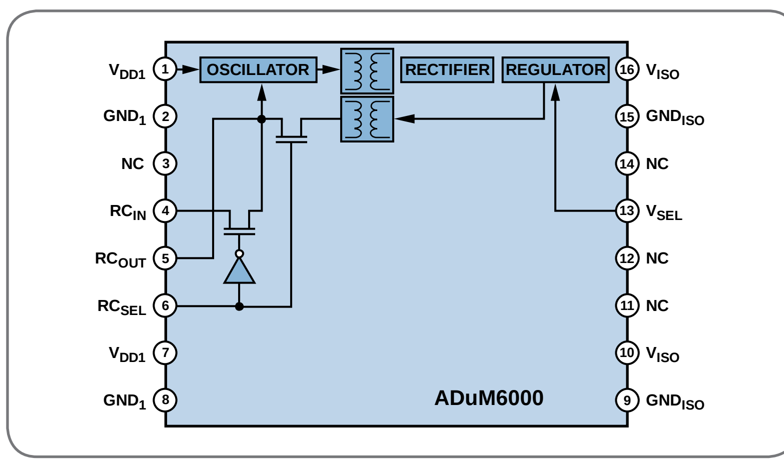
The ADuM4160 is designed to be integrated into a USB peripheral with an upstream facing USB port.

ADuM6000: Isolated Power for Isolated USB Applications

Isolated power is needed on either side of the isolation barrier in USB applications. Each side can provide its own power. For example, a patient monitor is plugged into the wall, and a laptop is powered by its own battery. Another way to achieve power on either side of the isolation barrier is for the system to use an isolated dc-to-dc converter. Designers can use the ADuM6000 with an isolated power supply, or another source to provide power.

ADuM6000 Features

- *iso*Power® integrated, isolated dc-to-dc converter
- Regulated 5 V or 3.3 V output
- Up to 400 mW output power
- 16-lead SOIC package with >7.6 mm creepage
- High temperature operation: 105°C maximum
- High common-mode transient immunity: >25 kV/µs



ADuM6000 functional block diagram.

High Efficiency Power Management for Battery Operated Devices

Standard lithium coin cell batteries used in point-of-care healthcare devices provide a typical output voltage in the range of 2.0 V to 3.0 V. Some high performance portable systems are also powered by rechargeable Li-Ion batteries with a 3.0 V to 4.2 V output. The two main design challenges with battery operated systems with regards to power are the battery life and the battery output voltage.

Battery life can be extended by selecting components with very low quiescent and shutdown currents and by keeping the main power consuming devices, such as the host processor, in a sleep state as much as possible. The battery output level has to comply with all the IC operating voltages in the system, generally consisting of a mixture of components developed on different processes, thus different compliance voltages.

ICs used for high performance portable devices operate on a wide range of voltage rails. Even if all of the ICs can operate directly off the battery, some form of regulation, such as step-up regulator, step-down regulator, or both, will be required to maintain the highest system efficiency and longest battery life.

Linear Regulators

Part Number	Description	V_{OUT} (V)	I_{OUT} Max (mA)	V_{IN} Range V_{MIN} to V_{MAX}	Supply Current (µA)	$V_{DROPOUT}$ @ Rated I_{OUT} (mV)	Package
ADP121	CMOS, low quiescent	9 options: 1.2 to 3.3	150	2.5 to 5.5	40	90 to 120	WLCSP, TSOT
ADP122	CMOS, low quiescent	7 options: 2.5 to 3.3	300	2.3 to 5.5	45	85	LFCSP
ADP125	CMOS, 0.8 to 5 V	N/A	500	2.3 to 5.5	45	130	LFCSP
ADP150	CMOS, ultralow noise	7 options: 1.8 to 3.3	150	2.2 to 5.5	10	105	WLCSP, TSOT
ADP170	CMOS, low dropout	5 options: 1.2 to 2.8	300	1.6 to 3.6	260	66	TSOT
ADP220	Dual, low noise, high PSRR	7 options: 1.2 to 2.8	200	2.5 to 5.5	220	150	WLCSP

Switching DC-to-DC Regulators

Part Number	Description	V_{IN} Range (V)	V_{OUT} Options (V)	I_{OUT} Max (A)	I_{SW} Peak (A)	Supply Current (µA)	Switch Frequency	Package
ADP1612	Step-up	1.8 to 5.5	V_{IN} to 20, adjustable	—	1.4	1350	650 kHz, 1.3 MHz	MSOP
ADP2108	Synchronous step-down	2.3 to 5.5	1.0, 1.1, 1.2, 1.3, 1.5, 1.82, 1.8, 2.3, 2.5, 3.0, 3.3	0.6	1.3	30	3 MHz	WLCSP
ADP2138	Synchronous step-down	2.3 to 5.5	8 options: 0.8 to 3.3	0.8	1.5	30	3 MHz	WLCSP
ADP2139	Synchronous step-down with load discharge switch	2.3 to 5.5	8 options: 0.8 to 3.3	0.8	1.5	30	3 MHz	WLCSP
ADP2504	Synchronous buck-boost	2.3 to 5.5	2.8, 3.3, 3.5, 4.2, 4.5, 5.0	1	1.3	50	2.5 MHz	LFCSP

Multioutput Regulators

Part Number	Product Description	V_{IN} Range (V)	Number of Outputs	Switching Frequency (MHz)	Buck (mA)	LDO (mA)	Key Features	Package
ADP2140	Low quiescent current buck converter with 300 mA LDO regulator	2.3 to 5.5 (LDO: 1.7 to 5.5)	2	3	600	300	Auto sequence; power good	LFCSP
ADP5020	General-purpose PMU	2.4 to 5.5	3	3	300, 600	150	I^2C, programmable outputs	LFCSP
ADP5022	Dual buck regulator with 150 mA LDO	2.4 to 5.5	3	3	150, 500	150	—	WLCSP
ADP5025	System PMU for digital still cameras	2.45 to 5.5	9	2.5	700, 900	50	I^2C, RTC, back-batt charger	WLCSP
ADP5030	Dual LDO (V_{OUT} = 1.2 V, 2.8 V) with load switch	2.5 to 5.5	3	—	—	200, 200	Load switch and level shifters	WLCSP

Display Backlight Controllers

ADI backlight drivers (controllers) are appropriate for display backlighting, keypad control, and status indicators. They extend battery life by reducing processor interaction and ambient light sensing (ALS) complexity. These intelligent state-machine products improve battery life by reducing processor interaction and improve time to market by reducing software complexities. User interface is also enhanced by the on-chip built-in controllers for automatic light adjustment based on ambient conditions.

Backlight Controllers

Part Number	Description	LED Number	LED Configuration	Topology	Application	I²C Support	Max I_{OUT} (mA)	Brightness Control	Peak Efficiency (%)	Switching Frequency (MHz)
ADP5501	WLED driver with ALS, RGB	6	Serial	Inductive	Backlighting	Yes	30	I²C	—	1
ADP5520	WLED driver with ALS, RGB, KBRD	6	Serial	Inductive	Backlighting	Yes	30	I²C	—	1
ADP8860	WLED driver with ALS	7	Parallel	Capacitive	Backlighting	Yes	60	I²C	89	1
ADP8861	WLED driver	7	Parallel	Capacitive	Backlighting	Yes	60	PWM	89	1.32
ADP8863	Fun lighting LED driver	7	Parallel	Capacitive	Backlighting	Yes	60	I²C	89	1.32
ADP8870	WLED driver with ALS and CABC	7	Parallel	Capacitive	Backlighting	Yes	60	I²C	89	1.2

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I²C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

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