Texas Instruments

TI HealthTech

Engineering components for life.

2013

Applications Guide

www.ti.com/healthtech

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TI's HealthTech Applications Guides available for individual download:

- **Health**
- **Imaging**
- **Fitness**

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Introduction

HealthTech Overview

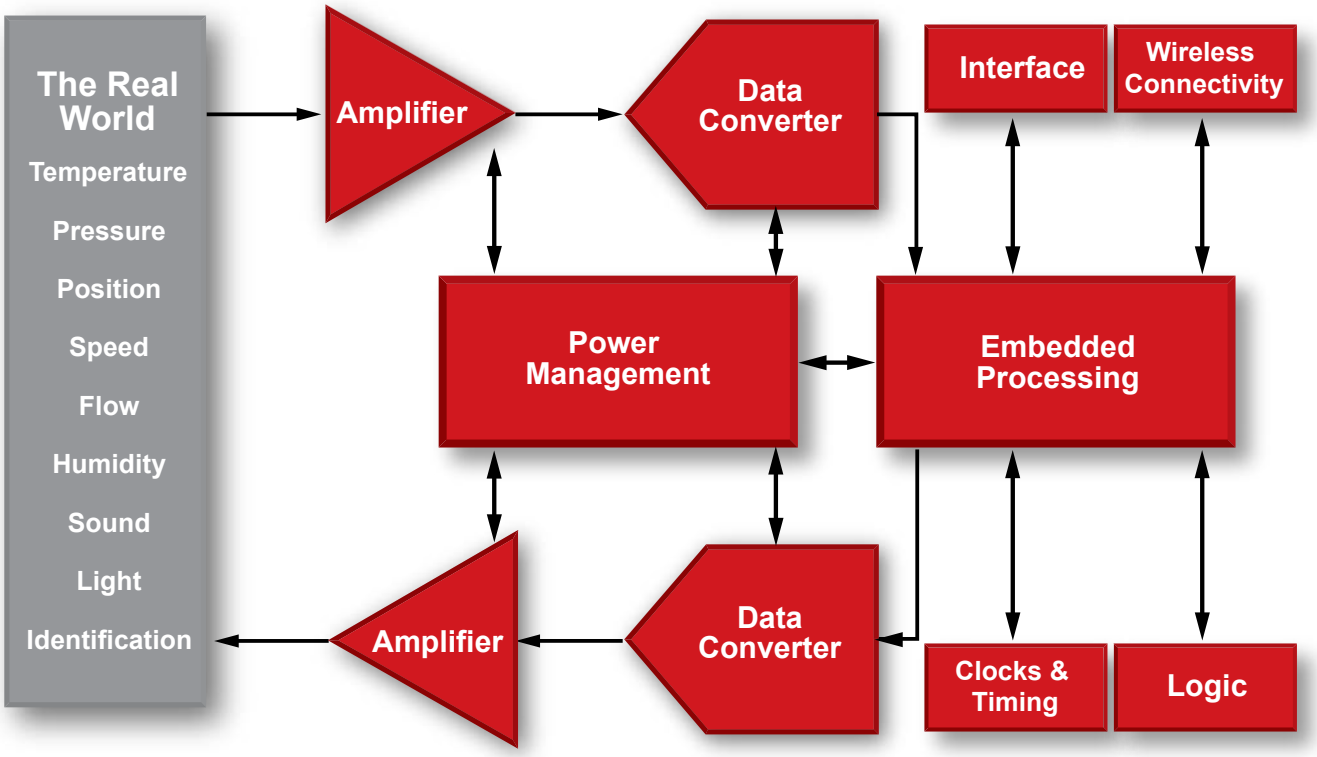
TI HealthTech is passionate about developing innovative components to promote healthier lives, and is committed to continually advancing the landscape for healthcare around the world. With unequaled expertise in analog and embedded processing, TI HealthTech provides superior components for health, fitness and medical imaging, making healthcare more flexible, affordable and accessible.

TI HealthTech strives to build long-lasting relationships that benefit customers and their products to the highest degree, focusing on quality, reliability and responsive service. TI HealthTech's broad portfolio, backed by the resources of the TI global enterprise, is the world's largest producer of analog and embedded processors and the single most experienced source for healthcare components.

This latest guide makes it easier than ever for you to explore TI HealthTech's IC portfolio for healthcare applications. We feature a broad array of comprehensive system block diagrams, selection tables and key design tools to help you accelerate innovation.

You will find component suggestions and support for your healthcare application design in the following segments, which are also available at www.ti.com/healthtechguides for individual chapter download:

- Health
- Fitness
- Imaging



Analog connects the digital and real worlds.

Overview

Health Overview

More than ever, TI HealthTech is passionate about taking professional treatments beyond the hospital and into physician offices and patient homes. Both clinical and home health equipments, such as pulse oximetry and blood glucose meters, are challenged to extend battery life and make devices more wearable and accessible – without sacrificing accuracy or reliability. By developing innovative ways to increase integration, lower noise, and lower power consumption, TI components make healthcare more flexible, affordable and accessible.

Traditional clinical equipment such as digital stethoscopes, patient monitoring, ECG, EEG, and pulse oximetry have all become more portable through improvements in battery and battery management technologies, and the proliferation of wireless communications technologies like *Bluetooth*® and ZigBee®. The addition of features like touch screen control and audio feedback have taken away the complicated mix of knobs and dials and replaced them with menu-driven displays and user prompts.

TI features a broad array of comprehensive system block diagrams, selection tables and key design tools to help you accelerate innovation. TI HealthTech's broad portfolio, backed by the resources of the TI global enterprise, is the world's largest producer of analog and embedded processors and the single most experienced source for healthcare components in both clinical and home health applications.

Design Considerations

Given the broad nature of this medical subsegment, design considerations are broken down into some popular motor control and sensor interface applications. Simple system block diagrams are provided along with analog and embedded processing solutions.

Referring to the motor control block diagram example, small electromechanical drives can include solenoid drives, single-direction small electromechanical drives include solenoid drives, single-direction DC, bidirectional DC or brushless DC systems and are typically sized according to their frame size and power in watts. Digital controllers, software, and complementary analog and digital solutions from TI can help solve most drive requirements.

Core Subsystems

Controllers

TI offers a range of solutions for the control processor, from the ultra-low power MSP430 microcontroller to the C2000™ and Tiva™ C Series ARM® Cortex-M4F microcontrollers. The right controller can optimize motor drive efficiency, improve reliability and lower overall system costs. The 32-bit DSP-class performance- and motor-control optimized on-chip peripherals of C2000 controllers enable users to easily implement advanced algorithms such as sensorless vector control of three-phase motors. The C2000 DSC family offers software-compatible controllers ranging from the low-cost F28016 to the industry's first floating-point DSC, the TMS320F28335.

Motor/Solenoid Drive Circuit

PWM drivers like the 1.2-A DRV104 are compatible with resistive or inductive loads for driving solenoids or valves from a single supply. New PWM power drivers such as the DRV8811 provide an integrated stepper motor solution that includes two H-bridge drivers as well as microstepping indexer logic for stepper control. For higher drive currents, try a high-voltage, high-current op-amp with a current limit between 0 and 5 A (OPA548) externally controlled via a resistor/potentiometer or a current-out DAC like the DAC7811 or DAC8811. MOSFET drivers such as UCC37321 or the UCC37323 can drive small motors directly or drive power devices such as MOSFETs or IGBTs.

Isolation

TI digital isolators have logic input and output buffers separated by TI's silicon dioxide (SiO2) isolation barrier, providing 4 kV of isolation. Used in conjunction with isolated power supplies, these devices block high voltage, isolate grounds, and prevent noise currents from entering the local ground and interfering with or damaging sensitive circuitry.

Designers might consider the new ISO1050, which is a galvanically isolated CAN transceiver that meets or exceeds the specifications of the ISO11898 standard, with IEC 61010-1 approval pending. As a CAN transceiver, the ISO1050 provides differential transmit capability to the bus and differential receive capability to a CAN controller at signaling rates up to 1 megabit per second (Mbps).

Designed for harsh environments, the ISO1050 provides additional features such as failsafe outputs, 50-kV/µs transient immunity, and the 3.3-V inputs are 5V-tolerant.

Design Considerations

Controller Interface

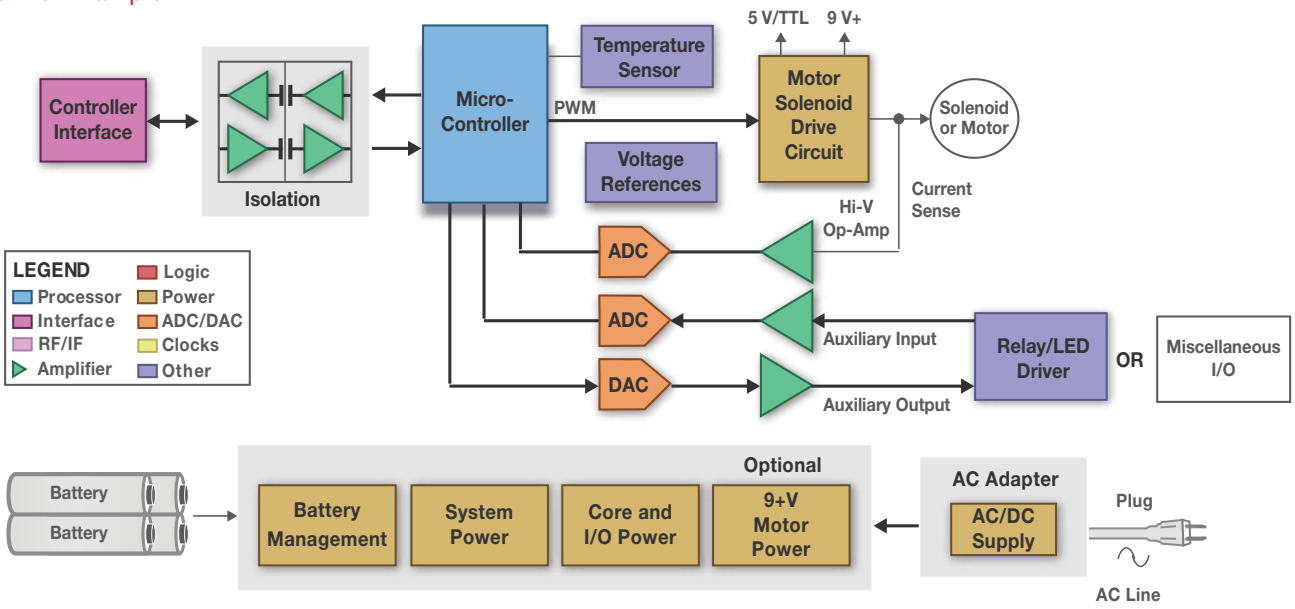
USB, RS-232 or RS-422 are adequate for many systems. RS-485 signaling may be bundled with protocols such as Profibus, Interbus, Modbus or BACnet, each tailored for the specific requirements of the end user. Sometimes CAN or Ethernet/IP (industrial protocol) are preferred due to network requirements. M-LVDS can provide a lower power dissipation alternative.

Motion Feedback

Isolated delta-sigma modulators (AMC1203/AMC1210) are ideal for shunt measurements to flatten glitches and increase current feedback resolution. These modulators are easy to use and provide oversampling and filtering for an encoder. For measuring controller inputs and system feedback, the INA159 difference amplifier provides ±10 V (20-V pp) signals for an analog-to-digital converter (ADC) using 5-V or 3.3-V supplies.

ADCs like the ADS7861/ADS7864 or ADS8361/ADS8364 provide four- or six-channel simultaneous current sampling. The INA19x (x = 3 to 8) and INA20x (x = 1 to 9) provide wide common-mode voltages and are capable of both low-side and high-side current shunt monitoring.

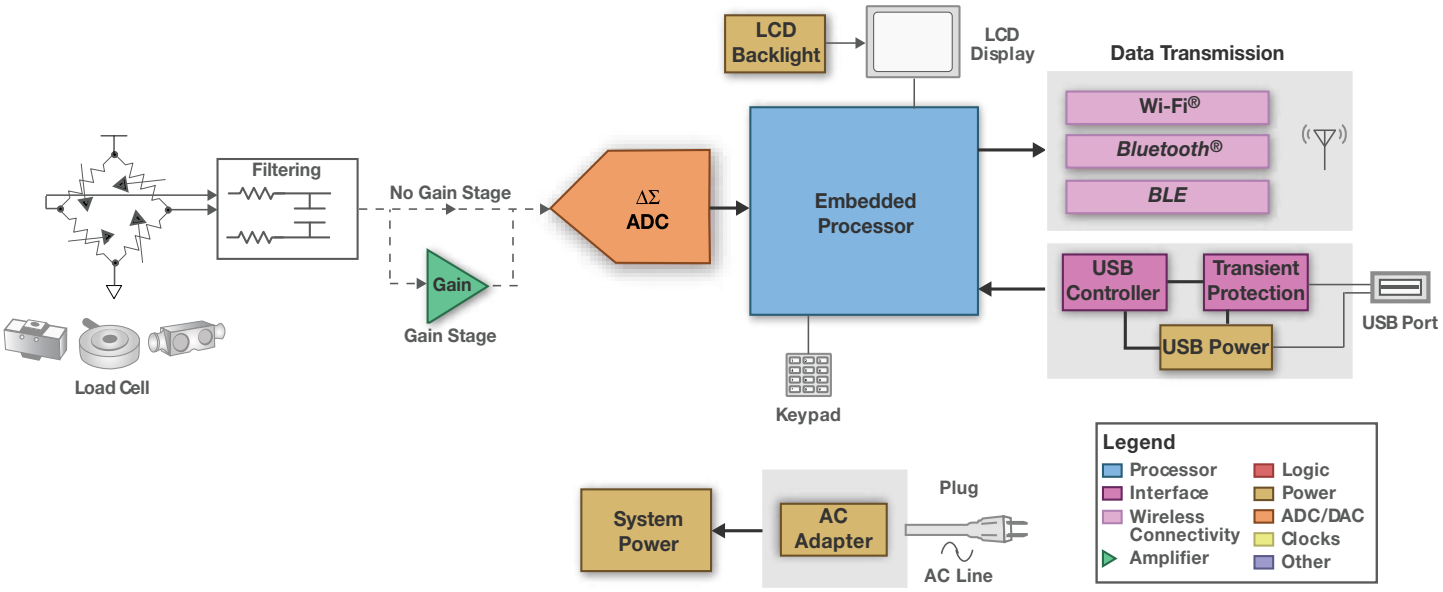
Motor Control Example



Design Considerations

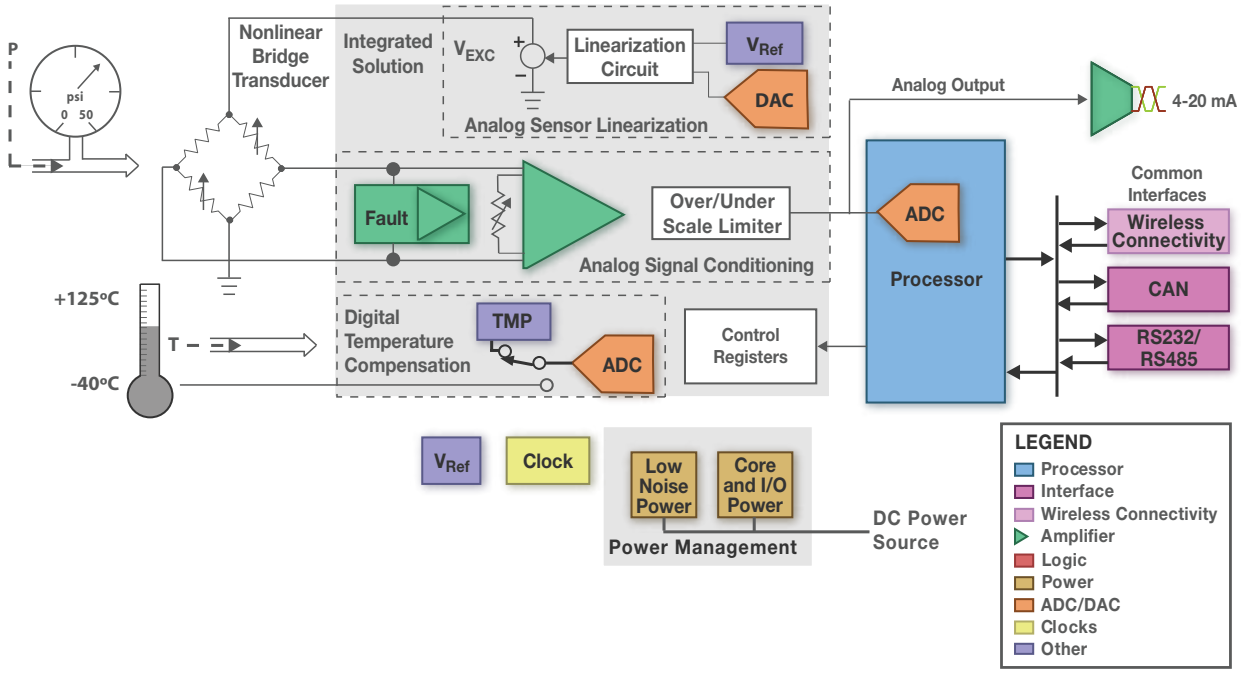
Sensor Signal Chain

Weigh Scale Sensor Example



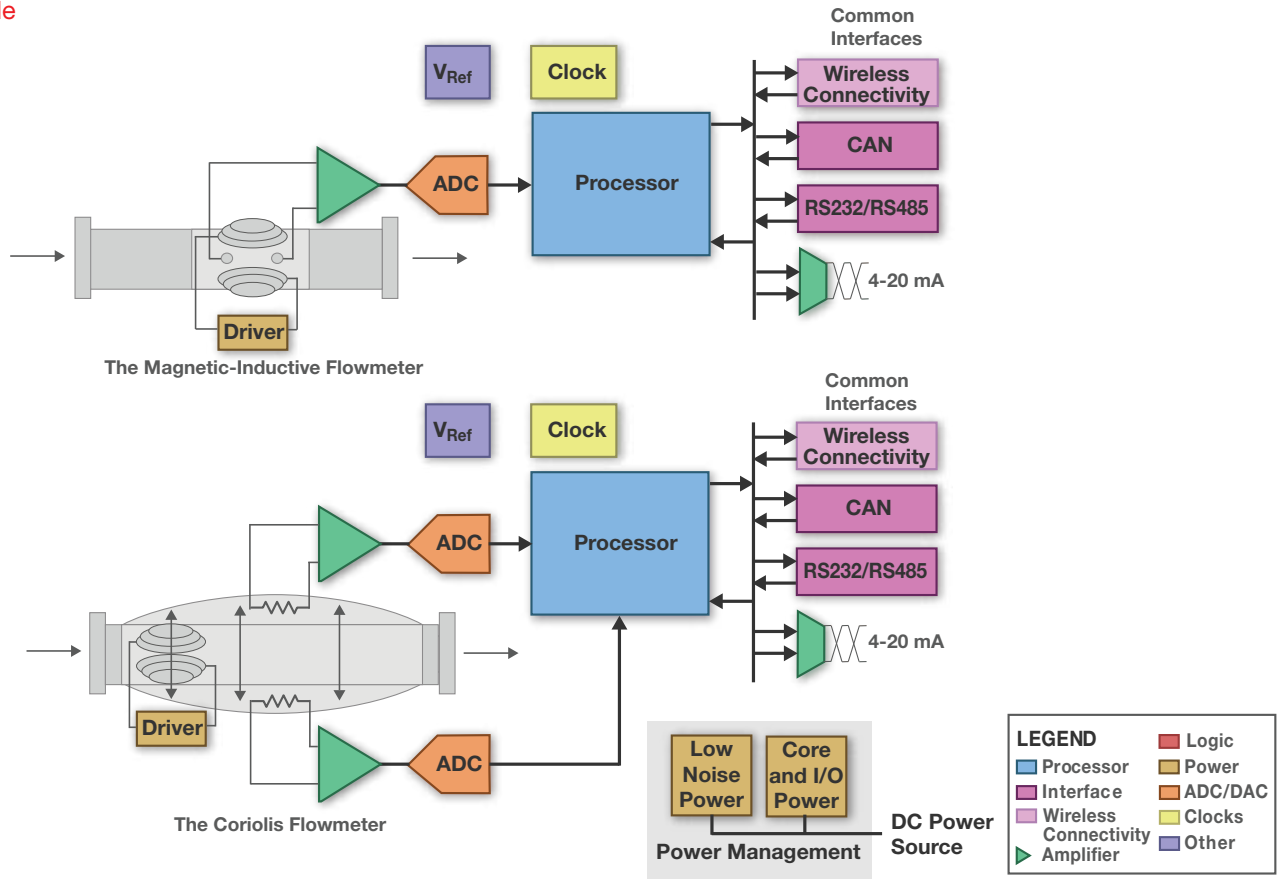
Sensor Signal Chains

Pressure Sensor Signal Chain Example



Design Considerations

Flow Meter Sensor Signal Chain Example



Sensor Interface

Electronic weigh scales, pressure sensors and flow meters are among the most common forms of measurement in the medical instrumentation market. Manufacturers of medical instruments occasionally develop proprietary ASICs to tailor the performance of the analog front end for the highest accuracy and stability possible, while maintaining an IP edge over their competition. Although TI supports and encourages this custom ASIC approach, there are design approaches using standard products offering up to 23 noise-free bits of resolution, which parallels the performance of customized solutions.

A major challenge in designing for these sensor interfaces is the sampling of multiple load cells while offering extremely low referred-to-input (RTI) noise. The ADS1230, ADS1232 and ADS1234 offer the low RTI noise required in this application.

Another important factor is the analog circuitry's long-term stability with regard to offset drift and gain over time and temperature, especially since real-world sensors have span and offset errors ever changing as temperatures rise and fall. In addition, many bridge pressure sensors have a nonlinear output with applied force. Here, the accuracy of the amplified input signal, either single-ended or differential, must be guaranteed over years of operation.

Auto-zero amplifiers such as the OPA335 and the INA326 instrumentation amplifier easily meet these stringent requirements by achieving offset drifts of 0.05µV/°C (OPA335) and 0.4µV/°C (INA326).

There are highly integrated solutions as well, such as the PGA309, tailored for bridge pressure sensors. These sensors comprise precision, low-drift programmable gain instrumentation amplifiers using auto-zero techniques and include programmable fault monitors and over/under scale limiters. The PGA309 also offers a digital temperature compensation circuit. If temperature compensation is not required, try the PGA308.

Other recommended lowest noise amplifiers and instrumentation amplifiers for pressure sensor conditioning include the OPAx227, OPAx132, INA118, INA122 and INA333.

The INA333 is becoming a popular choice for several applications within medical instrumentation, selected for its low power, high accuracy and gain-setting capabilities. A single external resistor sets any gain from 1 to 1,000 using the standard gain equation $G = 1 + (100k\Omega/RG)$.

Design Considerations

Analog to Digital Conversion

For analog to digital conversion, the ADS125x family of devices are well suited. These are precision, wide dynamic range, delta-sigma ADCs with 18- to 24-bit resolution operating from a single +5V supply and guaranteed to have no missing codes. They are designed for high-resolution measurement applications in cardiac diagnostics and medical instrumentation.

If multi-axis motor control is required, consider the new ADS8556/7/8 converter family. These ADCs contain six low-power, 16-, 14- or 12-bit successive approximation register (SAR)-based analog-to-digital converters (ADCs) with true bipolar inputs. Each channel contains a sample-and-hold circuit that allows simultaneous high-speed multi-channel signal acquisition supporting data rates of up to 740kSPS in parallel interface mode, or up to 500kSPS if the serial interface is used. As appropriate for motor control application, a wide input configuration range is possible from ±1V to ±12V.

Clocks

The CDCE9xx clock family comprises modular, PLL-based, low-cost, high-performance, programmable clock synthesizers, multipliers and dividers. They generate up to nine output clocks from a single input frequency. Each output can be programmed in-system for any clock frequency up to 230MHz using independent configurable PLLs.

Power

Low dropout regulators (LDOs) are good for low noise power for amplifiers and data converters because they provide low-ripple power rails leading to better signal fidelity. The REF31xx family comprises precision, low-power, low-dropout series voltage references available in a tiny SOT23-3 package. The REF31xx does not require a load capacitor, but is stable with any capacitive load and can sink/source up to 10 mA of output current.

Embedded Processing

OMAP™/DaVinci™ Processors

One of the most important features in today's medical instruments is ease of use. Ease of use can be achieved with touch-screen displays and multi-level menu-driven profiles that can be configured for the environment as well as the patient's vital statistics. Data transfer across everything from wireless to RS232 needs to be possible as well. Hospitals may support a specific infrastructure throughout all areas; ambulance, home and other environments may need support for different protocols.

The challenges in implementing this ease of use is strikingly similar to cellular phone systems. The OMAP 3 processor performs further digital signal processing, measurements and analytics to monitor equipment and patient conditions. A powerful ARM processor runs a high-level OS (HLOS), which makes adding multi-modal equipment control monitoring easy and provides extensive user interface and system control. Detecting abnormal conditions or faults and communicating to a central server or health care provider is essential. OMAP 3 has an extensive peripheral set to support various control and interface/connectivity options such as *Bluetooth*® technology, WiFi, ZigBee® and other emerging standards.

The Tiva™ C Series ARM® MCU Family of Processors

Medical instrumentation requires accuracy, reliability and responsiveness. Whether connected or standalone, Tiva C Series processors offer solutions useful to medical equipment manufacturers. Safety is enhanced through an MPU (memory protection unit), multiple error detection mechanisms in the processor, peripheral fault detection, priority of interrupts to handle faults and critical operations, and a highly deterministic operation. Communications include Ethernet and serial for connected devices.

Tiva C Series ARM Cortex-M4 Microcontrollers offer a direct path to the strongest ecosystem of development tools, software and knowledge in the industry. Designers who migrate to the Tiva C Series will benefit from great tools, small code footprints and outstanding performance.

The Tiva C Series product line is the industry's only family to have a floating-point unit enabled across the entire product line of ARM Cortex-M4F microcontrollers. Gracefully balancing performance with low power consumption, the Tiva C Series microcontrollers give customers the performance needed create highly responsive mixed-signal applications without burdening the design with a big power budget.

Tiva C Series microcontroller users will benefit from:

- Assured product longevity, with the backing of a global top-three semiconductor supplier with more than 75 years of industry experience.
- Access to and support from a large direct global sales force, in addition to extensive global distribution access.
- Ability to pair your Tiva C Series MCU with the complete signal chain and power management solutions, support and applications know-how that only TI can offer.

The era of pervasive 32-bit computing, control and communication has arrived.

Other Embedded Processors

The MSP430 microcontroller provides functions including calculation and signal processing, a friendly user interface such as LCD display and keypad control, and wireless/wired data transfer and connectivity interfaces. TI's MSP430 and MSC12xx integrated microcontroller solutions family allow the definition of filters and thresholds of critical pressure levels by including integrated ADCs.

Blood Pressure Monitors

Blood Pressure Monitors

These monitoring systems use Korotkoff, oscillometry or pulse transit time methods to measure blood pressure. A pressure cuff and pump, along with a transducer, are used to measure blood pressure and heart rate in three phases: inflation, measurement and deflation. Also included are LCDs, selection buttons, memory recall, power management and USB interface.

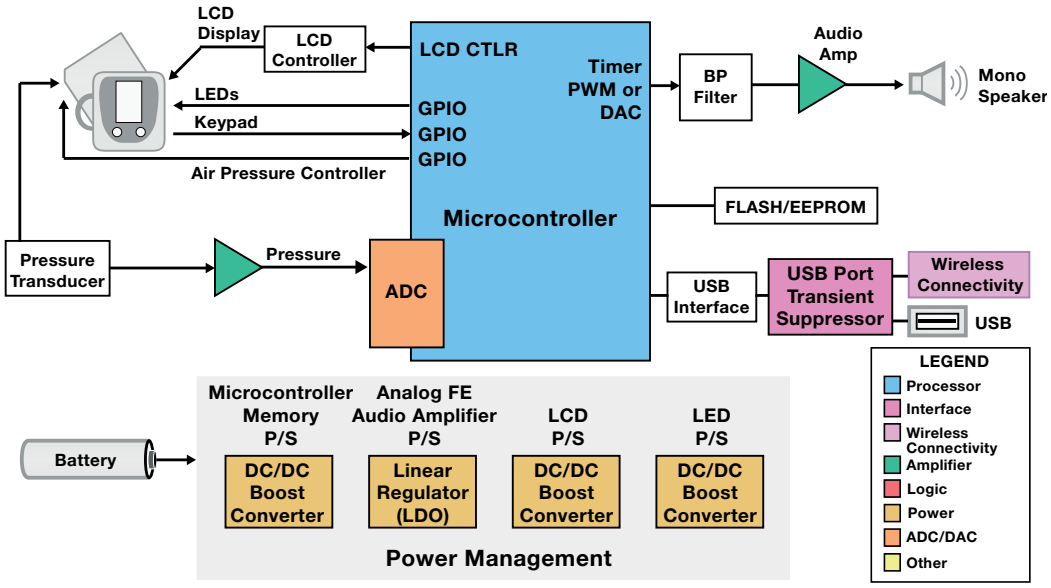
The core subsystems include:

Processor/Memory — Digital pressure measurement and heart rate are performed by the microcontroller. Measurement results are stored in flash memory as a data log that can be uploaded to a computer via USB or wireless connection.

User Interface — Allows the user to control the pressure measurement process and read the results on an LCD display.

Sensor Interface — Allows the processor to control the cuff inflation/deflation and sense blood pressure that is amplified by instrumentation amplifiers and digitized by the ADC.

Power Management — Converts input power from the alkaline or rechargeable batteries to run various functional blocks.



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Example application block diagram — blood pressure monitor.

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA321	CMOS Instrumentation Amp	0.02% accuracy, 2ppm/°C drift for gain = 5; 10pA input bias current	High gain accuracy	INA2321 (dual)
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA326, INA321
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
TPA2006D1	Analog-Input Class-D Amp	1.45W mono, filter-free Class D, 1.8V shutdown		
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	
Data Converters				
ADS1115	Delta-Sigma ADC	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC – 2.0 x 1.5 x .04mm leadless QFN pkg – reduces system size/component count	ADS1113/4, ADS1013/14/15
Processors				
MSP430F449	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 1KB/2KB RAM, 2x SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, HW multiplier	
MSP430FG43x	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD	12 ch. 12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amp, HW multiplier	
MSP430FG47x	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 2KB RAM, SPI + I^2C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	

Blood Glucose and Other Diagnostic Meters

New innovations in diagnostic equipment are making it easier than ever to test quickly for a number of critical care assays in blood such as blood gases, glucose, electrolytes, coagulation, chemistries, hematology and cardiac markers (cTnI). With the advent of new digital technologies, invasive blood analyzers have become portable and are used to measure the two major assays of metabolic disorders in blood system: glucose and cholesterol.

The two methods used for blood analyte measurement are the color reflectance method and the amperometric method (electrochemical sensor technology).

The analog front-end of the reflectance method uses topical sensors (LED, photo transistors) and a transimpedance amplifier. Measurements made using the color reflectance method are based on reaction color intensity in the reaction layer of the test strip by reflectance photometry. The meter quantifies the color change and generates a numerical value that represents the concentration of cholesterol/glucose in blood.

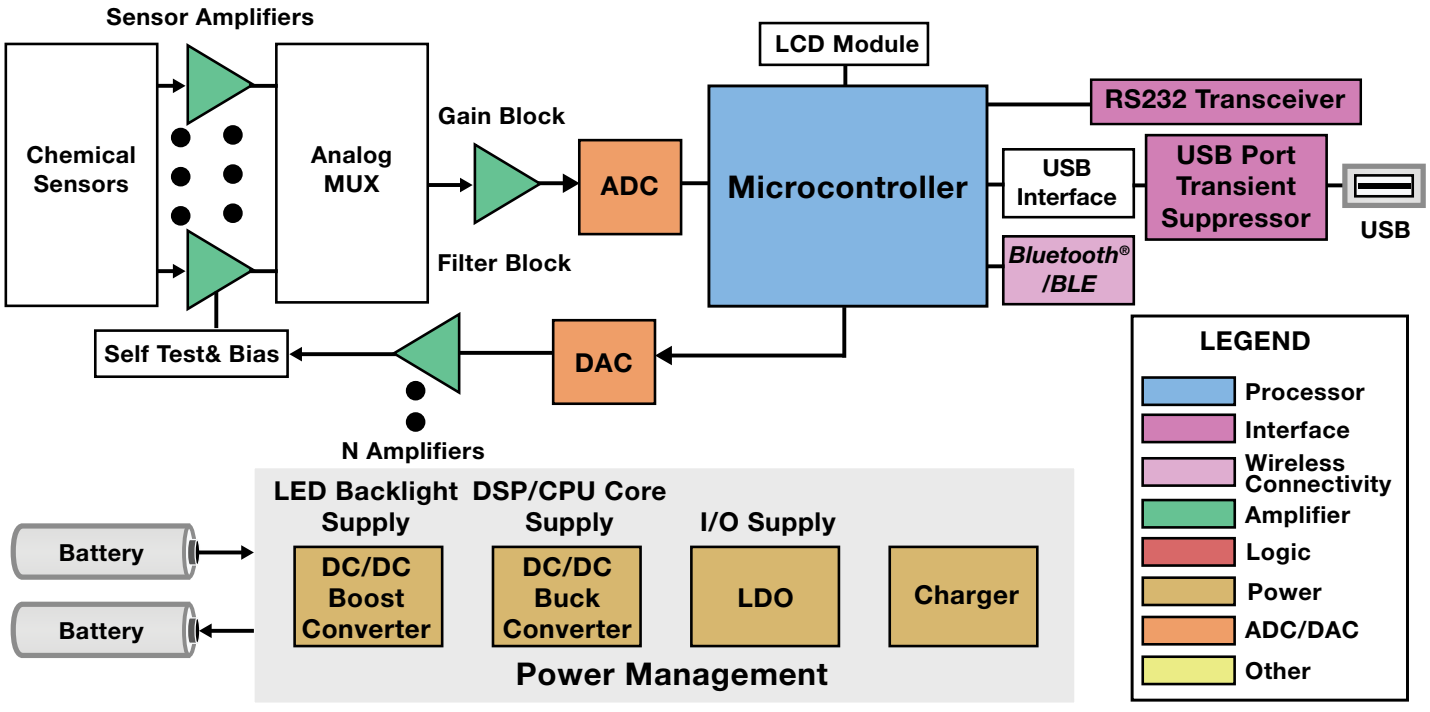
Using the amperometric method, the biosensor (test strip) is connected directly to the transimpedance amplifier. Cholesterol/glucose present in the blood, while undergoing chemical reaction with the test strip, generates charge and is measured by the amperometric method. An ambient temperature measurement is also necessary for test strip characteristic compensation.

The measurement sequence is usually controlled by a microcontroller (MCU). The MCU also processes the conversion results, storing the measurements in an EEPROM or Flash memory and controlling other functions such as the keypad, real-time clock, sound/speech compression and serial communication to a connected computer.

The audio output is provided by either a PWM circuit or from the DAC. Both can be used to generate beeping sounds to signal when measurement results are available. They also generate voice instructions from the speech-synthesizer software using ADPCM compression algorithms. Measurement results are stored with the measurement time and date in the EEPROM or Flash memory as a data log that can be uploaded to a computer via wireless interface.

MEDICAL DESIGN EXCELLENCE AWARDS® SUPPLIER TO A 2009 WINNER

Awarded for the True2go portable glucose monitor by Home Diagnostics Inc.



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Portable blood gas analyzer block diagram.

Blood Glucose and Other Diagnostic Meters

16-Bit, Ultra-Low-Power Microcontrollers

MSP430FG477, MSP430FG478, MSP430FG479

Get samples and datasheets at: **www.ti.com/sc/device/PARTnumber** (Replace **PARTnumber** with **msp430fg477**, **msp430fg478** or **msp430fg479**)

View our video on MSP430™ 16-bit ultra-low-power MCU for portable medical devices at **www.ti.com/430medical**

Key Features

- Low supply-voltage range: 1.8V to 3.6V
- Ultra-low power consumption:
  - Active mode: 280µA at 1MHz, 2.2V
  - Standby mode: 1.1µA
  - Off mode (RAM retention): 0.1µA
- Five power-saving modes
- Wakes up from standby mode in less than 6µs
- 16-bit RISC architecture
- 125ns instruction cycle

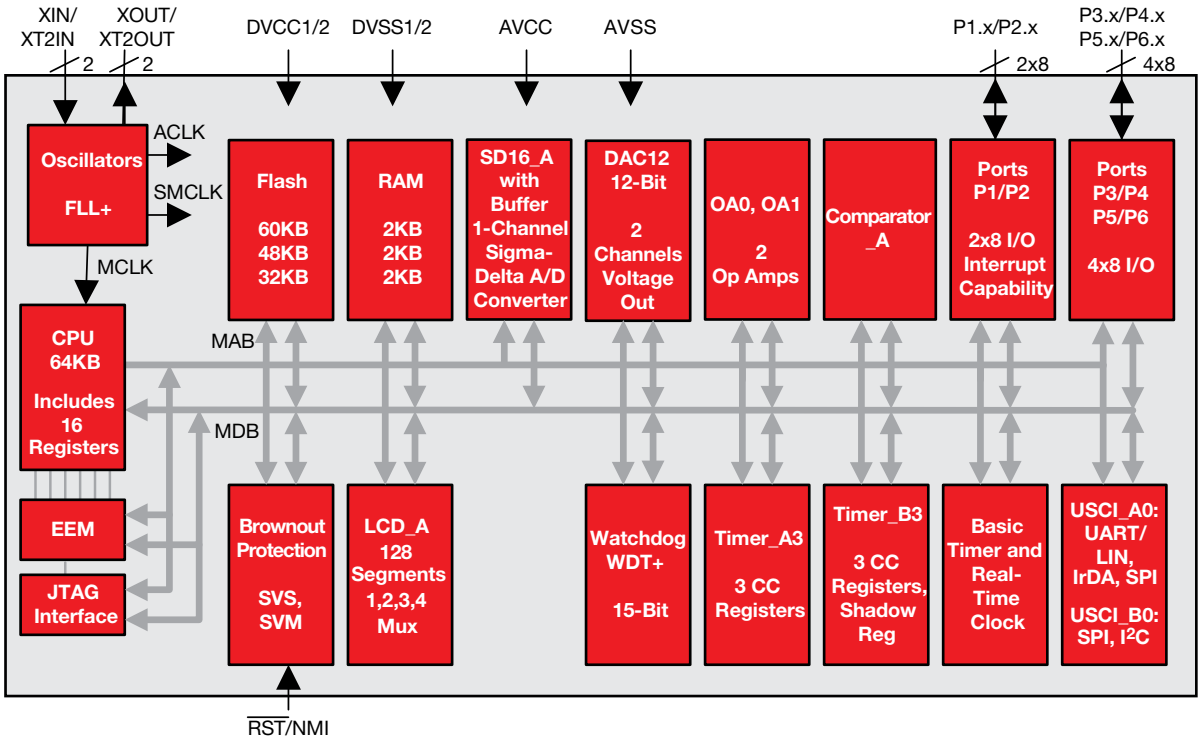
Applications

- Portable medical meters, such as blood glucose meters, pulse oximeters
- Insulin pumps
- Digital thermometers
- Heart rate monitors

TI's MSP430™ family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6µs.

The MSP430FG47x is a microcontroller configuration with two 16-bit timers, a basic timer with a real-time clock, a high performance 16-bit sigma-delta A/D converter, dual 12-bit D/A/ converters, two configurable operational amplifiers, two universal serial communication interface, 48 I/O pins, and a liquid crystal display driver with contrast control.

The MSP430FG47x is one of the SoC (System on Chip) series in the MSP430 portfolio. Because this device series has integrated the entire signal chain on-chip, it greatly simplifies the design of medical devices. In addition to enabling more compact products, this device series also reduces BOM (Bill of Materials) costs because of the need for fewer discrete components.



MSP430FG47x functional block diagram.

Blood Glucose and Other Diagnostic Meters

16-Bit, Ultra-Low-Power Microcontrollers

MSP430F5418A, MSP430F5419A, MSP430F5435A, MSP430F5436A, MSP430F5437A, MSP430F5438A

Get samples and datasheets at: **www.ti.com/sc/device/PARTnumber** (Replace **PARTnumber** with **msp430f5418a**, **msp430fF5419a**, **msp430F5435a**, **msp430f5436a**, **msp430f5437a** or **msp430f5438a**)

Key Features

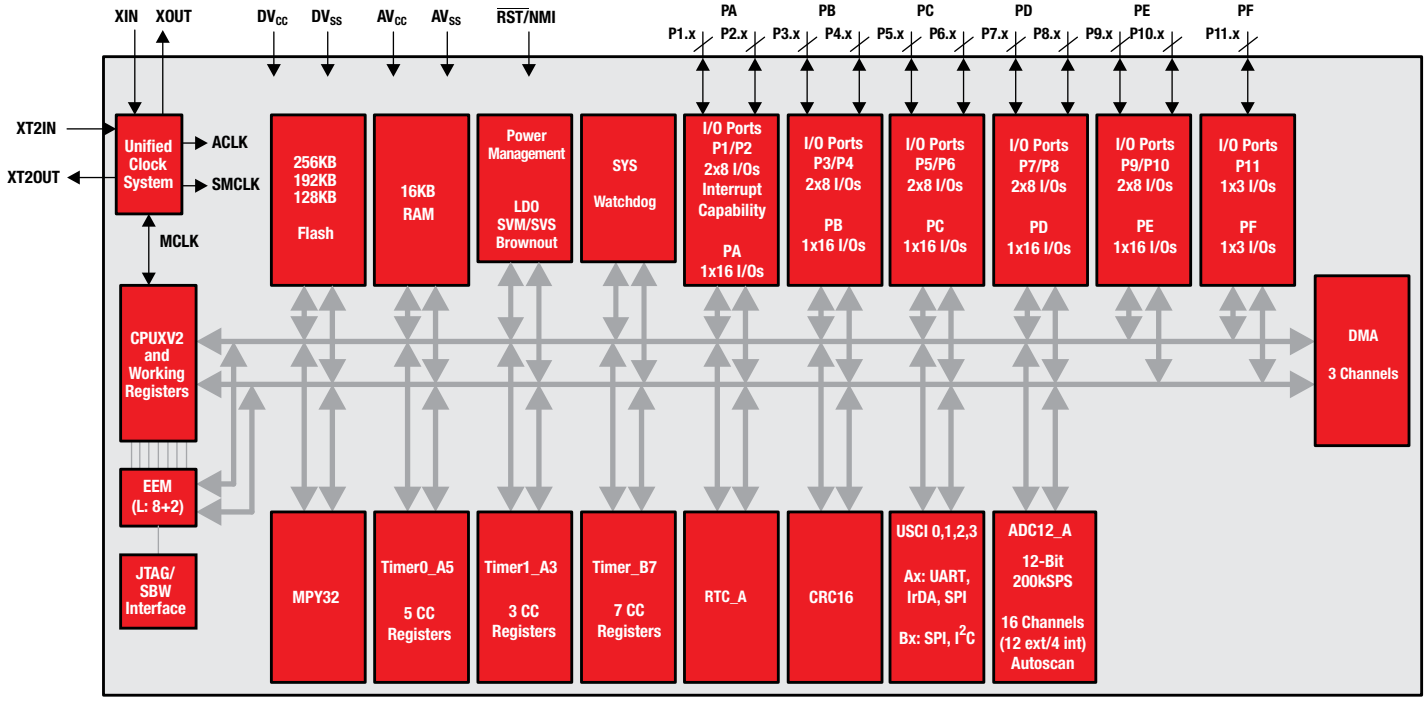
- Low supply-voltage range: 1.8V to 3.6V
- Ultra-low power consumption:
  - Active mode: 230µA/MHz
  - Standby mode (LPM3 RTC mode): 2.6µA
  - Off mode (LPM4 RAM retention): 1.6µA
  - Shutdown mode (LPM5): 0.1µA
- Wakes up from standby mode in less than 5µs
- 16-bit RISC architecture:
  - Extended memory
  - Up to 25MHz system clock

Applications

- Portable medical meters
- Blood pressure monitors
- Patient sensor systems

The MSP430F541x and MSP430F543x series of microcontroller configurations includes three 16-bit timers, a high-performance 12-bit ADC, up to four universal serial communication interfaces, a hardware multiplier, DMA, a real-time clock module with alarm capabilities, and up to 87 I/O pins. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications.

These device series are ideally suited for portable medical and fitness applications. With up to 256kB flash and 16kB RAM, they are capable of hosting the application as well as wireless protocols for medical devices with wireless capabilities. For example, the BlueMSPTM platform, which is comprised of the MSP430F5438 Experimenter's Board (MSP-EXP430F5438) and the BL6450 *Bluetooth*® Connectivity Card, can use the MSP430F5438 to host the *Bluetooth*® stack's Health Device Profile.



MSP430F54xx functional block diagram.

Blood Glucose and Other Diagnostic Meters

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA126	Instrumentation Amp	175µA/ch supply, 3µV/°C (max) drift, 250µV (max) offset	Precision low power, ±1.35V to ±18V supply	INA2126
INA321	CMOS Instrumentation Amp	0.02% accuracy, 2ppm/°C drift for gain=5; 10pA input bias current	High gain accuracy	INA2321 (dual)
INA332	Instrumentation Amp	0.07%, 2ppm/°C, G = 5 gain accuracy, 73dB CMRR, 0.5pA IB, 490µA (max/ch) IQ	Single or bipolar operation, low noise	INA326, INA338
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA326, INA321
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA365	Zero-Crossover Op Amp	1.8V to 5.5V, 50MHz BW, 25V/µs slew rate, 0.0004% (typ) THD+N, 4.5nV/√Hz at 100kHz, RRIO	Zero-crossover, high speed, low input bias, low noise, RRIO	
THS4131	High-Speed Op Amp	150MHz (–3dB) BW, 51V/µs SR, –100dB THD	Differential input/differential output	THS4120, THS4150
THS4521/22/24	Low Power FDA	1.14mA quiescent current (typ), 4.6nV/√Hz voltage noise, 2.5V to 5.5V supply	Low power, low noise enables high accuracy	
Data Converters				
ADS1115	Delta-Sigma ADC	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC – 2.0 x 1.5 x .04mm leadless QFN pkg – reduces system size/component count	ADS1113/4, ADS1013/14/15
ADS1271/74/78	Delta-Sigma ADC	24-bit, 128kSPS, 8-channel, 111dB SNR	Simultaneous measurement, onboard decimation filter	
DAC7554	VOUT DAC	Quad, 12-bit, 2.7V to 5.5V supply, 5µs settling time	Ultra-low glitch, ultra-low crosstalk	DAC7614, DAC7615
DAC7568	Octal DAC	Ultra-low glitch, voltage output DAC	Internal low drift reference	
DAC8411	High Resolution DAC	16-bit, low power DAC	Small size, wide supply range	DAC8311, DAC7311
DDC112	2 Channels	50pC to 100pC full-scale	Up to 3kSPS data rate, 40mW/Ch	SOIC-28 or TQFP-32
DDC114	4 Channels	12.5pC to 350pC full-scale	Up to 3.1kSPS data rate, 13.5mW/Ch	QFN-48
DDC118	8 Channels	12.5pC to 350pC full-scale	Up to 3kSPS data rate, 40mW/Ch	QFN-48
Data Converters				
MSP430FG43x	Ultra-Low-Power 16-bit MCU	32KB to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD	12 ch. 12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amp, HW multiplier	
MSP430FG47x	Ultra-Low-Power 16-bit MCU	32KB to 60KB Flash, 2KB RAM, SPI + I^2C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	
RF NFCs				
TRF7970A	Multi-Protocol Fully Integrated 13.56MHz RFID/ NFC Transceiver IC	NFCIP-1, NFCIP-2. Peer-to-peer, card emulation, reader/ writer functionality ISO14443A, ISO14443B, FeliCa, ISO15693 NFC software library available.	High level of integration enables reduction in system size and cost ultra low power capability extends battery life high level of flexibility and configurability	TRF7960

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Asset Security/Authentication

Single Wire Asset Authentication Device

BQ2026

Get samples and datasheets at: **www.ti.com/device/bq2026**

Key Features

- 1536 bits of one-time programmable (OTP) EPROM for storage of user-programmable configuration data
- Factory-programmed unique 64 bit identification number
- Single-wire interface to reduce circuit board routing
- Synchronous communication reduces host interrupt overhead
- 6KV IEC 61000-4-2 ESD compliance on data pin
- No standby power required
- Available in a 3-pin SOT23 package and TO-92 package

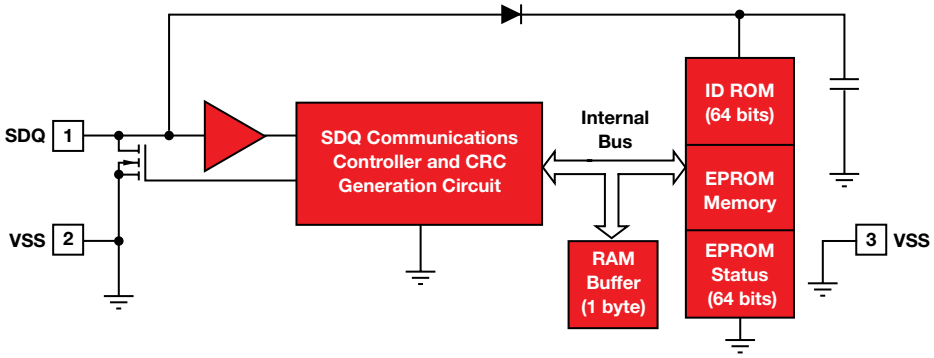
Applications

- Medical cable identification
- Blood glucose strip authentication and calibration
- Asset tracking and management
- Computer peripheral identification and labeling
- Battery packs
- Hardware identification for knock off prevention

The BQ2026 is a 1.5K-bit serial EPROM containing a factory-programmed, unique 48-bit identification number, 8-bit family code, and a 64-bit status register.

The BQ2026 SDQ interface requires only a single connection and a ground return. The SDQ pin is also the sole power source for the BQ2026.

The small surface-mount package options saves printed-circuit-board space, while the low cost makes it ideal for applications such as battery pack configuration parameters, record maintenance, asset tracking, product-revision status, and access-code security.



BQ2026 block diagram.

Patient Monitoring

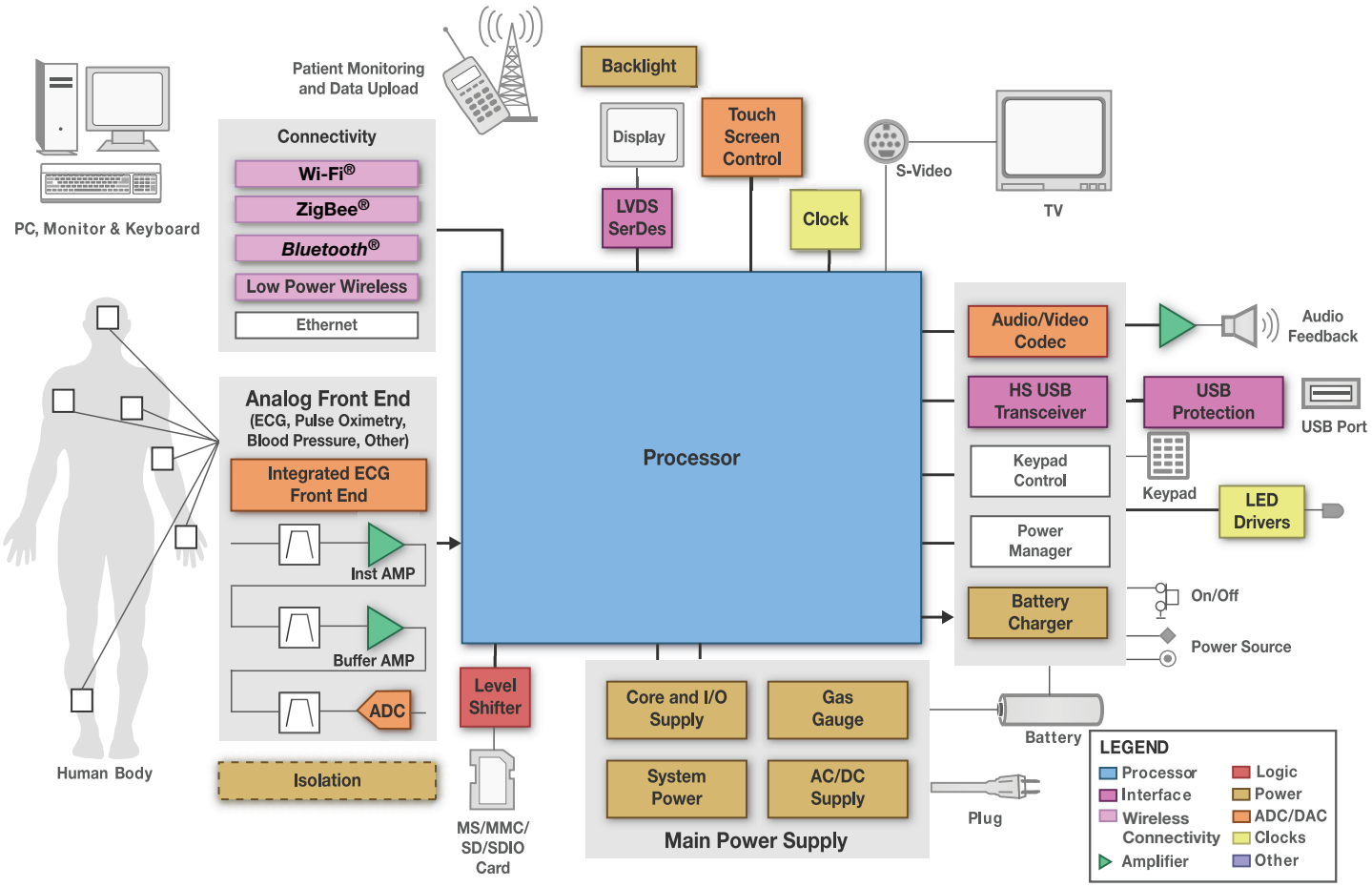
A variety of portable, single and multiple-parameter monitors have emerged over the last few years that measure blood pressure, glucose levels, pulse, tidal carbon dioxide and other biometric values. Patient monitors are portable, flexible devices that can be adapted to a wide range of clinical applications and support various wired and wireless interfaces.

Key Features

The most important features of today's patient monitors are mobility, ease-of-use and effortless patient data transfer. Mobility includes portability as well as the ability to interface with other medical devices such as anesthesia machines and defibrillators. Ease-of-use can be achieved with touch-screen displays and multi-level, menu-driven profiles that can be configured for the environment and the patient's vital statistics.

Data transfer across everything from wireless to RS-232 must be possible. While hospitals may support a specific infrastructure throughout all areas, ambulance, home and other environments often require support for different protocols.

An ongoing need to minimize healthcare costs is creating a move toward patient treatment and monitoring outside of the hospital. This shift is placing an emphasis on remote patient monitoring and telemedicine solutions that enable providers to treat patients in highly populated, rural and remote areas in emerging economies.



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Multi-parameter patient monitor system block diagram.

Patient Monitoring

TI's OMAP™/Davinci™ Technology Solution

The challenges involved in implementing patient treatment and monitoring equipment are similar to systems implementation challenges faced by the cellular phone industry. TI's OMAP™ technology, with embedded ARM® and DSP processor cores, directly addresses these challenges.

TI has an extensive portfolio of analog front-end solutions for essential signal conditioning. The OMAP 3 processor enables digital signal processing, measurements and analytics needed to monitor patient condition. TI's powerful ARM processor runs a high-level OS (HLOS) that makes adding multi-modal monitoring easy and provides extensive user interface and system control.

Detecting abnormal conditions and communicating to a central server are essential to providing timely and on-demand healthcare. OMAP 3 has an innovative peripheral set that supports connectivity options such as *Bluetooth*® technology, WiFi®, ZigBee® and other emerging standards.

Applications Processor
OMAP35x

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/omap35x**

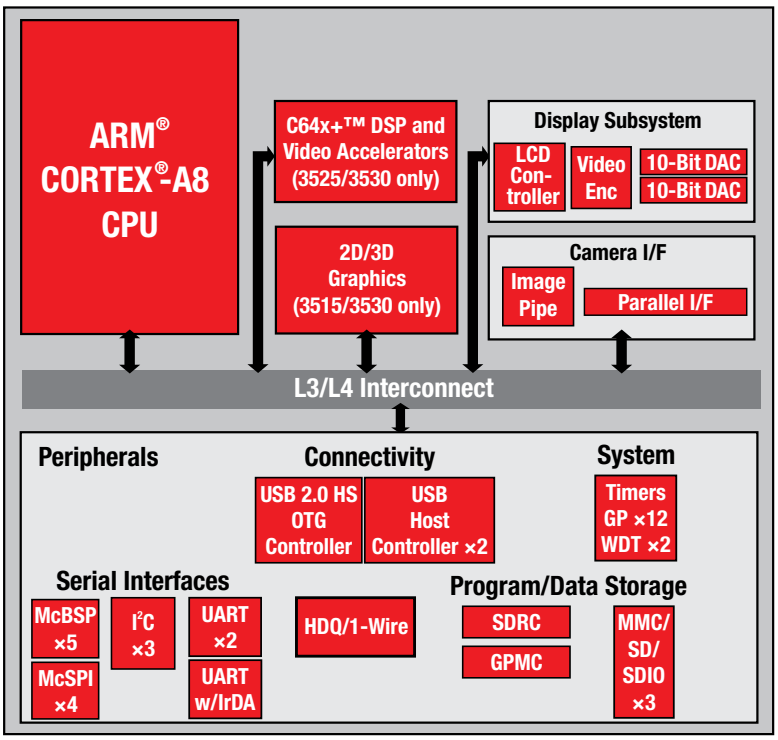
Key Features

- ARM® Cortex-A8 core
- TI's DaVinci™ C64x+™ DSP core
- 2D/3D graphics accelerator
- OpenGL® ES 2.0 compatible graphics engine
- Neon™ coprocessor
- Scalable platform:
  - OMAP3503 (ARM-only version)
  - OMAP3515 (ARM and 2D/3D graphics accelerator)
  - OMAP3525 (ARM and DSP)
  - OMAP3530 (ARM, DSP and 2D/3D graphics accelerator)
- Optimized laptop-like performance at handheld power levels in a single chip
- TI's SmartReflex™ power and performance management
- 65nm CMOS

Applications

- Multiparameter patient monitors
- Portable ultrasound
- Automatic external defibrillator (AED)
- Electrocardiogram (ECG)

The OMAP35x generation of processors includes four distinct single-chip processors with a variety of combinations of the ARM® Cortex-A8 core, multimedia-rich peripherals, OpenGL® ES 2.0 compatible graphics engine, video accelerators and the high-performing TMS320C64x+™ DSP core. Offering laptop-like performance at handheld power levels, the OMAP35x provides users with a highly flexible platform capable of creating a powerful user interface experience, with additional signal processing for application implementation. In addition, TI's SmartReflex™ power and performance management technologies reduce overall power consumption and optimize performance, allowing users to develop innovative, low-power applications. The processor provides a range of interfaces for analog front ends, power and battery monitoring, displays, keypads and touch-screen solutions. Also, support for various connectivity options such as USB, Wi-Fi®, ZigBee®, Ethernet and other emerging standards is integrated into the processor.



OMAP35x processor.

Patient Monitoring

Hercules™ RM48x Safety MCU

RM48x Family

Get samples, datasheets, evaluation modules at: **www.ti.com/rm4**

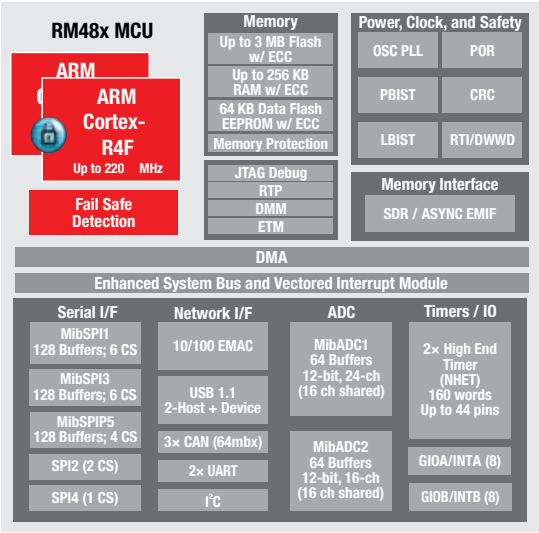
Key Features

- ARM Cortex-R4F core with floating-point support
- Up to 220MHz
- Lockstep safety features built-in simplify SIL-3 applications
- Up to 3-MB Flash/256-KB RAM with ECC
- Memory protection units in CPU and DMA
- Multiple network peripherals:
  - Ethernet, USB, CAN
- Flexible timer module with up to 44 channels
- 12-bit analog/digital converter
- External memory interface

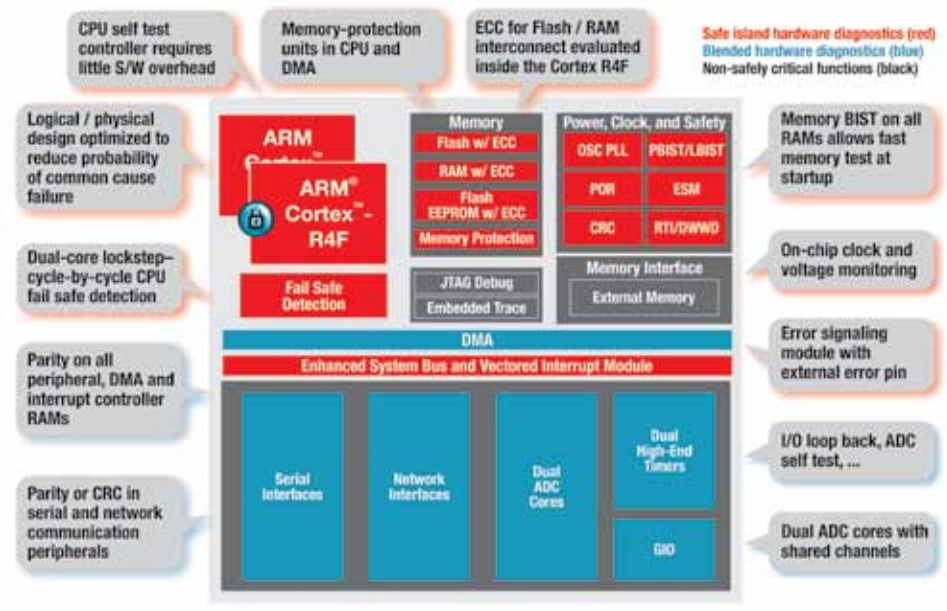
Applications

- Ventilators
- Infusion pumps
- Automated external defibrillators (AED)
- Patient monitoring
- Dialysis machine
- Continuous positive airway pressure (CPAP)

The RM48x is the highest performance Hercules Safety microcontroller family. Based on the ARM® Cortex™-R4F floating point core running at up to 220MHz it includes several flash memory and connectivity options. Developed with the capability to meet the requirements of the IEC 61508 SIL-3 safety standard and supporting many functional safety features including a dual-CPU lockstep architecture, hardware built-in self test (BIST), memory protection unit (MPU), error correction code (ECC) and parity checking, the RM4x safety microcontrollers provide a high level of diagnostic coverage without costly safety software overhead. A wide choice of communication interfaces makes this family an ideal solution for safety critical industrial and medical applications.



Packages: LQLP: 144 pin - 20 x 20; nfBGA: 337 pin - 16 x 16, 0.8mm; –40 to 105°C temperature range.



Patient Monitoring

Tiva™ C Series
TM4C123x

Get samples and datasheets at: **www.ti.com/tiva-c**

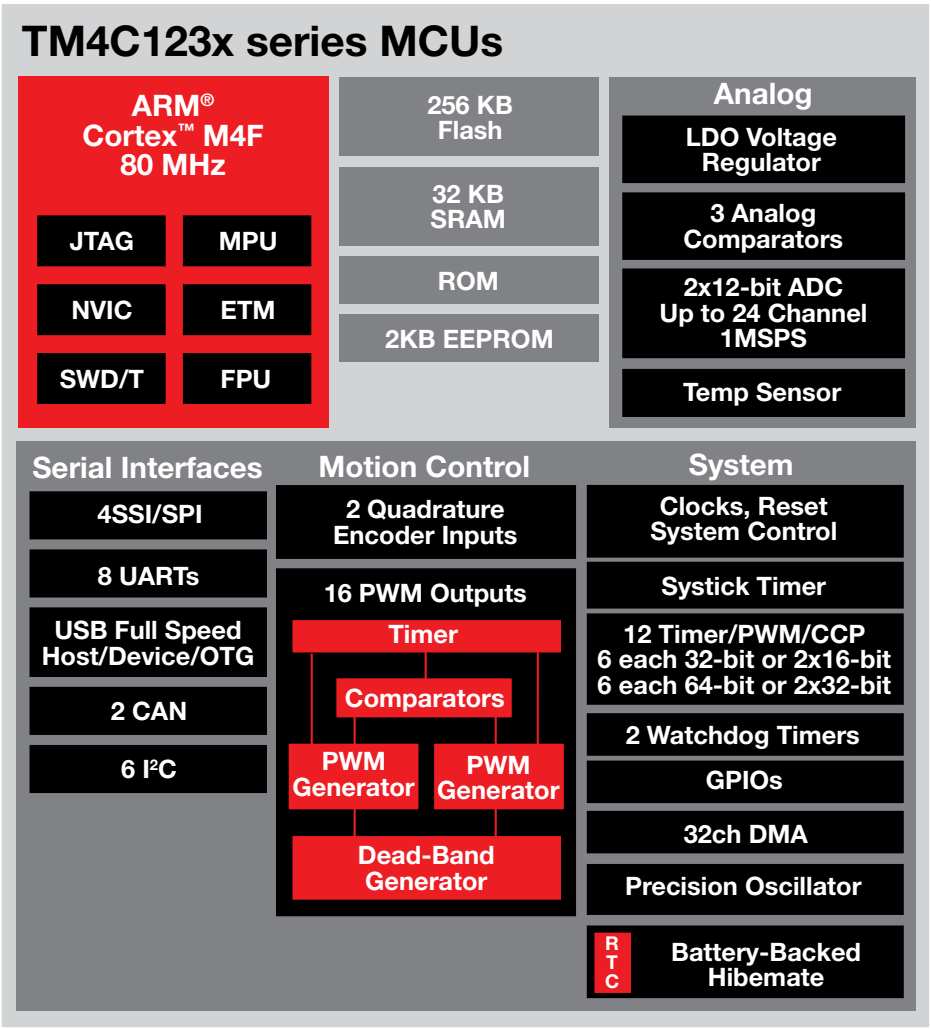
Key Features

- Performance:
  - ARM® Cortex™-M4F core up to 80 MHz
- Power:
  - Active power as low as 375 µA/MHz
  - Low-power modes down to 1.6 µA
- Integration:
  - Up to 40 PWM outputs, 2 QEIs
  - Up to 24 timers
  - 12-bit ADCs up to 1 MSPS
  - Up to 20 serial ports-UART, I^2C, SPI/SSI
  - CAN A/B, USB 2.0 OTG/H/D

Applications

- Security and access control
- Home and building automation
- Industrial automation
- Human machine interface
- Lighting control
- System management

The Tiva C Series microcontrollers provide a broad portfolio of floating point enabled ARM Cortex-M4F MCUs. Designers who migrate to the Tiva C Series MCUs benefit from a balance between the performance needed to create highly responsive mixed-signal applications and the low power architecture required to address increasingly aggressive power budgets. Tiva C Series MCUs are supported by TivaWare™ for C Series, designed specifically for those customers who want to get started easily, write production-ready code quickly, and minimize their overall cost of software ownership.



Tiva™ C Series family block diagram.

Patient Monitoring

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA126	Instrumentation Amp	±250µV (max) input offset, 83dB CMRR, 0.175mA (typ) I_Q	Precision low power, ±1.35V to ±8V supply	INA2126, INA122
INA128	Instrumentation Amp	60µV offset, 0.7 µV/°C drift, 8nV/√(Hz) noise	Low noise, low drift, wide supply, wide BW	INA118, INA129
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA326
OPA2822	High-Speed Amp	Dual, 2nV/√Hz noise, 240MHz GBWP, 90mA output, 4.8mA/ch I_Q, +5V to +12V supply	High speed, wide input and output voltage swing, excellent DC accuracy	OPA2690, OPA842
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05 µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA376	Precision Op Amp	7.5nV/√Hz noise, 760µA(typ)/ch Iq, 5µV (typ) offset, input EMI filter, RRO	Low noise, low power, low input bias	OPA340, OPA337, OPA364
OPA378	Low Noise Precision Op Amp	0.1µV/°C Vos drift, 125µA, 900kHz, 0.4μV_{PP} (0.1Hz to 10Hz) 0.4µ V_{pp} (0.1Hz to 10Hz), 0.9MHz	Lowest noise, power, price, precision zero-drift option	OPA330, OPA333
OPA695	High-Speed Amp	1.4GHz BW (G = +2), 4300V/µs slew rate, 129mW power, ±4.2V output voltage swing	Wide bandwidth, current feedback, low power, fast signal conditioning	OPA847, OPA691
TPA2006D1	Analog-Input Class-D Amp	1.45W mono, filter-free Class D, 1.8V shutdown		
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA3007D1	Analog-Input Class-D Amp	Mono, medium power, filter-free Class D		
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	
Data Converters				
ADS1115	Delta-Sigma ADC	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC, 2.0 x 1.5 x .04mm leadless WFN pkg; reduces system size and componenent count	ADS1113/4, ADS1013/14/15
ADS1298	ECG/EEG AFE	24-bit, 8 PGA, 8 ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1294, ADS1296, ADS1198, ADS1258
ADS7866	SAR ADC	12-bit, 200kSPS, 71dB SNR, ±1.5 LSB (max) INL, 1.6V to 3.6V supply	Small size, low power, serial interface	ADS7886
ADS7924	Low-Power SAR ADC	12-bit, 100kSPS, 4 channel, ≤1µA power down current, I^2C interface, QFN package	Intelleigent system power management and self monitoring	ADS7828, ADS7823
ADS8201	Micropower SAR ADC	8 channel, 12-bit, 100kSPS, 1.32mW power consumption at 100kSPS	Full on-chip data acquisition system	ADS7870
ADS8326	SAR ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL, SE input	Low power, small package, and wide supply range	ADS8317
TLV320AIC3104	Audio Codec	Low-power stereo codec, 6 inputs, 6 outputs, headphone amp, enhanced digital effects		
TLV320DAC3120	Low-Power Audio DAC	Mono DAC with 2.5W mono Class-D speaker amplifier; miniDSP for audio processing	Longer battery life, better audio quality, lower cost	TLV320DAC3101
TLV320DAC32	Audio DAC	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		
Processors				
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM® Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM3517	Applications Processor	ARM® Cortex-A8, graphics acelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
OMAP3530	Applications Processor	ARM® Cortex-A8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at handheld power levels	OMAP3503, OMAP3515, OMAP3525
OMAP-L137	Low-Power Applications Processor	300MHz ARM9™ w/MMU + 300MHz C674x™ floating-point DSP core, rich peripheral set including 10/100 Ethernet MAC, LCD controller, USB 2.0 HS OTG, USB 1.1 full speed, SPI and MMC/SD	Highly integrated, dual-core solution drives low system cost and maximum flexibility for connectivity, GUI and high-level OS options. Extends product battery life by providing greater than 60% power reduction over existing solutions in the market.	OMAP-L138
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Patient Monitoring

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC1120	Sub-1GHz RF Transceiver	Industry leading RF blocking and selectivity: 65dB adjacent channel rejection at 12.5kHz offset 90dB blocking. High output power (up to +16dBm) and excellent sensitivity (–123dBm @1.2kbps). WaveMatch; Advanced DSP sync detector with high sensitivity and strong noise immunity.	The most robust RF transceiver on the market. Reliable communication in presence of RF interference. Up to 139dB RF link budget. More reliable links, no false sync detects in noise. Enables RF sniff mode with <3mA current consumption.	
CC2520	2.4GHz ZigBee®/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temperature range; AES-128 security module	Reliable RF link with interference present; 400m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10 dBm Tx power with transmit power control, –93 dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10 dBm Tx power with transmit power control, –93 dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC2530/31	Second Gen. System-on-Chip Solution for 2.4GHz IEEE 802.15.4/RF4CE/ ZigBee®	Excellent RX sensitivity, low power, easy to use development tools	RF design system-on-chip for quick time to market. Provides a robust and complete ZigBee® USB dongle or firmware-upgradable network node.	CC2590/91, CC2530ZNP
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
Processors				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Biophysical Monitoring Overview

The human medical data acquisition system, in particular the patient monitoring system, presents the challenge to designers of measuring very small electrical signals in the presence of much larger common-mode voltages and noise. Front-end amplifiers perform the essential conditioning that complements downstream digital processing, which in turn refines the measurement and communicates with other systems. Biophysical measurements include electrical and mechanical signals for general monitoring, diagnostic and scientific purposes both in clinic and non-clinic environments. Successfully meeting the signal acquisition challenge requires system designers to have knowledge of the signal source, good design practice and ICs with appropriate characteristics, features and performance.

Signal Acquisition Challenges

The action potential created by heart wall contraction spreads electrical currents from the heart throughout the body. The spreading electrical currents create different potentials at different points on the body, which can be sensed by electrodes on the skin surface using biological transducers made of metals and salts. This electrical potential is an AC signal with bandwidth of 0.05Hz to 100Hz, sometimes up to 1kHz. It is generally around 1mV peak-to-peak in the presence of much larger external high frequency noise plus 50/60Hz interference normal-mode (mixed with the electrode signal) and common-mode voltages (common to all electrode signals).

The common-mode is comprised of two parts: 50Hz or 60Hz interference and DC electrode offset potential. Other noise or higher frequencies within the biophysical bandwidth come from movement artifacts that change the skin-electrode interface, muscle contraction or electromyographic spikes, respiration (which may be rhythmic or sporadic), electromagnetic interference (EMI), and noise from other electronic components that couple into the input. Some of the noise can be cancelled with a high-input-impedance instrumentation amplifier (INA), like the INA333 or INA118, which removes the AC line noise common to both inputs and amplifies the remaining unequal signals present on the inputs; higher INA common-mode rejection (CMR) will result in greater rejection. Because they originate at different points on the body, the left-arm and right-arm ECG signals are at different voltage levels and are amplified by the INA. To further reject 50 and 60Hz noise, an operational amplifier deriving common-mode voltage is used to invert the common-mode signal and drive it back into the patient through the right leg using an amplifier. Only a few microamps or less are required to achieve significant CMR improvement and stay within the UL544 limit.

Supply Voltage

As in most other applications, the system supply voltage in biophysical monitoring continues the trend toward low, single-supply levels. While bipolar supplies are still used, 5V systems are now common and trending to single 3.3V supplies. This trend presents a significant challenge for the designer faced with at least a 300mV DC electrode potential and emphasizes the need for a precision signal-conditioning solution.

Frequency Response

Standard –3dB frequency bandwidth for patient monitoring is 0.05Hz to 30Hz, while diagnostic grade monitoring requires 0.05Hz to 100Hz or more. The analog front end must be AC coupled to remove artifacts from the electrode offset potential.

Instrumentation Amplifier Requirements

- Stability in low gain (Gain = 1 to 10)
- High common-mode rejection
- Low input bias current (I_B)
- Good swing to the output rail
- Very low offset and drift

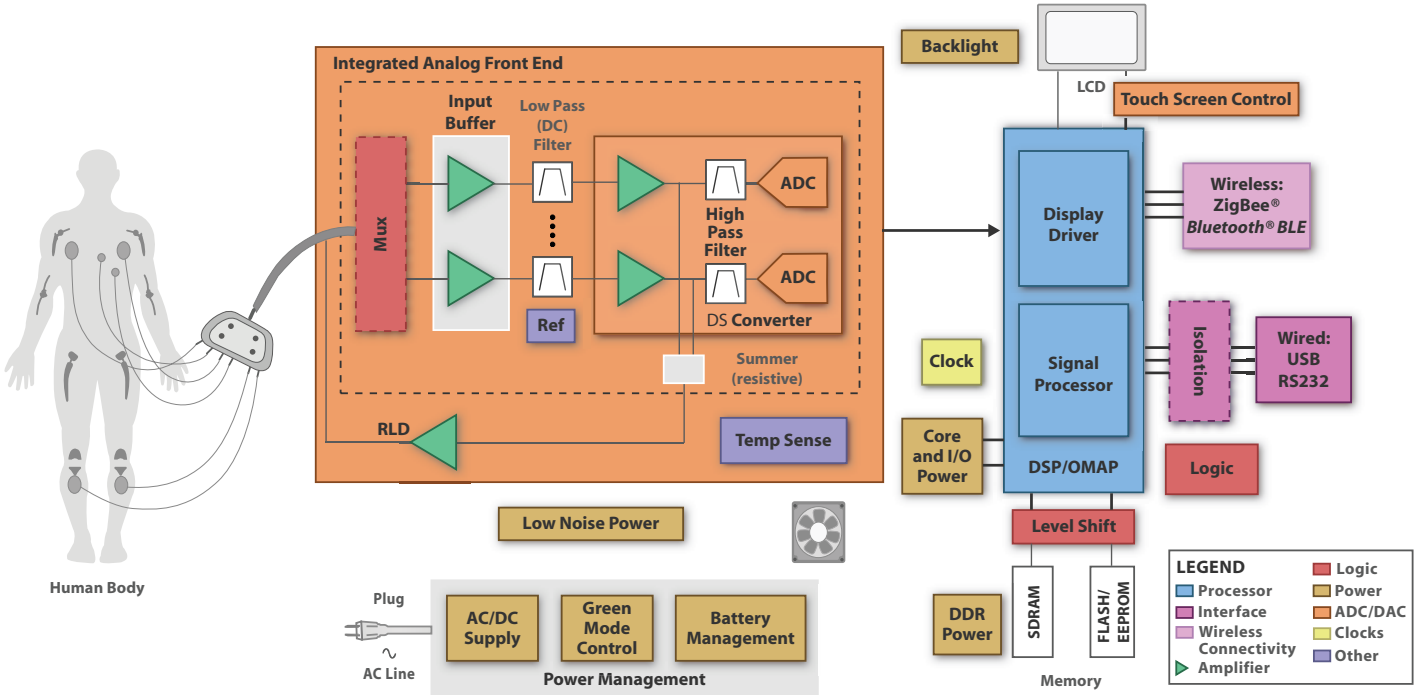
Operational Amplifier Requirements

- Low noise in high gain (Gain = 10 to 1000)
- Rail-to-rail output
- Very low offset and drift

Connectivity for ECG/EEG equipment has become of interest as caregivers require data to move from medical end equipment to data hubs such as the hospital/clinic IT infrastructure, computers or even mobile phones.

For more information, visit www.ti.com/ecg

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)



Three ECG electrodes connected to patient using CMOS components w/5V single supply. This circuit will operate on a 3.3V supply.

Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

ADS1298ECG Front End Performance Demonstration Kit
ADS1298ECGFE-PDK

Get samples and datasheets at: **www.ti.com/sc/device/ADS1298ecgfe-pdk**

Key Features

- Easy-to-use evaluation software for Microsoft™ Windows XP
- Built-in analysis tools including oscilloscope, FFT, and histogram displays
- Flexible input configurations
- Optional external reference circuits
- Ability to export data in simple test files for post processing

The ADS1298ECG FE is a reference design for the ADS1298, a simultaneous sampling, 24-bit, delta-sigma (ΔΣ) analog-to-digital converter (ADC) with a built-in programmable gain amplifier (PGA), internal reference, and an onboard oscillator. The ADS1298 incorporates all of the features that are commonly required in medical electrocardiogram (ECG) and electroencephalogram (EEG) applications. The ADS1298ECG FE can be used with a variety of patient simulators and allows the user to take advantage of the flexible input multiplexer which can be independently connected to the internally-generated signals for test, temperature, and lead-off detection.

ADS1298ECG front end performance demonstration kit.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Low-Power, 8-Channel, 24-Bit Analog Front End for Biopotential Measurements
ADS1298

Get samples and datasheets at: **www.ti.com/sc/device/ads1298**

Key Features

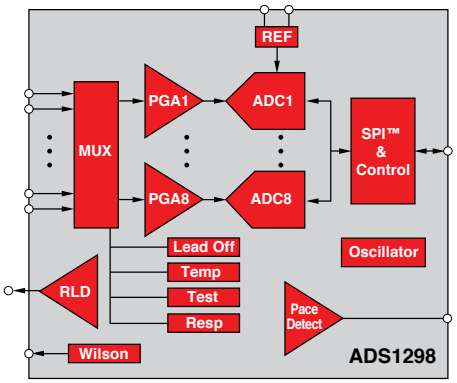
- Eight low-noise PGAs and eight high-resolution ADCs (ADS1298)
- Low power: 0.75mW/channel
- Input-referred noise: 4µVPP (150Hz BW, G = 6)
- Input bias current: 200pA (max)
- Data rate: 250SPS to 32kSPS
- CMRR: –115dB
- Programmable gain: 1, 2, 3, 4, 6, 8 or 12
- Built-in right leg drive amplifier, lead-off detection, WCT, test signals

Applications

- Medical instrumentation (ECG and EEG), including:
  - Patient monitoring; holter, event, stress, and vital signs ECG, AED, telemedicine, fetal ECG
  - Bispectral index (BIS), evoked audio potential (EAP), sleep study monitor
- High-precision, simultaneous, multichannel signal acquisition

The ADS1294/6/8 is a family of multichannel, simultaneous sampling, 24-bit, delta-sigma (ΔΣ) analog-to-digital converters (ADCs) with a built-in programmable gain amplifier (PGA), internal reference and onboard oscillator. The ADS1294/6/8 incorporates all of the features that are commonly required in medical electrocardiogram (ECG) and electroencephalogram (EEG) applications.

With its high levels of integration and exceptional performance, the ADS1294/6/8 family enables the creation of scalable medical instrumentation systems at significantly reduced size, power and overall cost.



ADS1298 functional block diagram.

Biopotential Sensing (ECG/EEG) Delta-Sigma ADCs

Device	Res. (Bits)	Sample-Rate (kSPS)	Number of Input Channels	Interface	Input-Referred Noise (µVpp)	Common Mode Rejection (dB)	Power (mW)	HiRel Avail.	Package(s)	Price*
ADS1298	24	32	8 Diff	SPI	4	115	6	N	BGA-64, TQFP-64	23.95
ADS1298R	24	32	8 Diff	SPI	3	115	6	N	BGA-64	23.95
ADS1296	24	32	6 Diff	SPI	4	115	5.1	N	BGA-64, TQFP-64	17.95
ADS1293	24	25.6	3 Diff	SPI	10	100	0.9	N	QFN = 28	5.5
ADS1294	24	32	4 Diff	SPI	4	115	3.6	N	BGA-64, TQFP-64	11.95
ADS1198	16	8	8 Diff	SPI	12	100	4.5	N	BGA-64, TQFP-64	8.00
ADS1196	16	8	6 Diff	SPI	12	100	3.9	N	BGA-64, TQFP-64	11.95
ADS1194	16	8	4 Diff	SPI	12	100	3	N	BGA-64, TQFP-64	15.95

**Suggested resale price in U.S. dollars in quantities of 1,000.*

*New products are listed in **bold red.***

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

24-bit, Low Noise AFE for EEG Applications

ADS1299

Get samples and datasheets at: **www.ti.com/sc/device/ads1299**

Key Features

- Fully integrated solution
  - 8 low-noise programmable amps
  - 8 high-resolution ADC's
  - Test signals, bias amp, oscillator & ref
- Outstanding performance
  - Noise: 1uV p-p (@ 70Hz BW)
  - CMRR: 120dB
- Continuous lead-off detect option
- Pin compatible with ADS1298

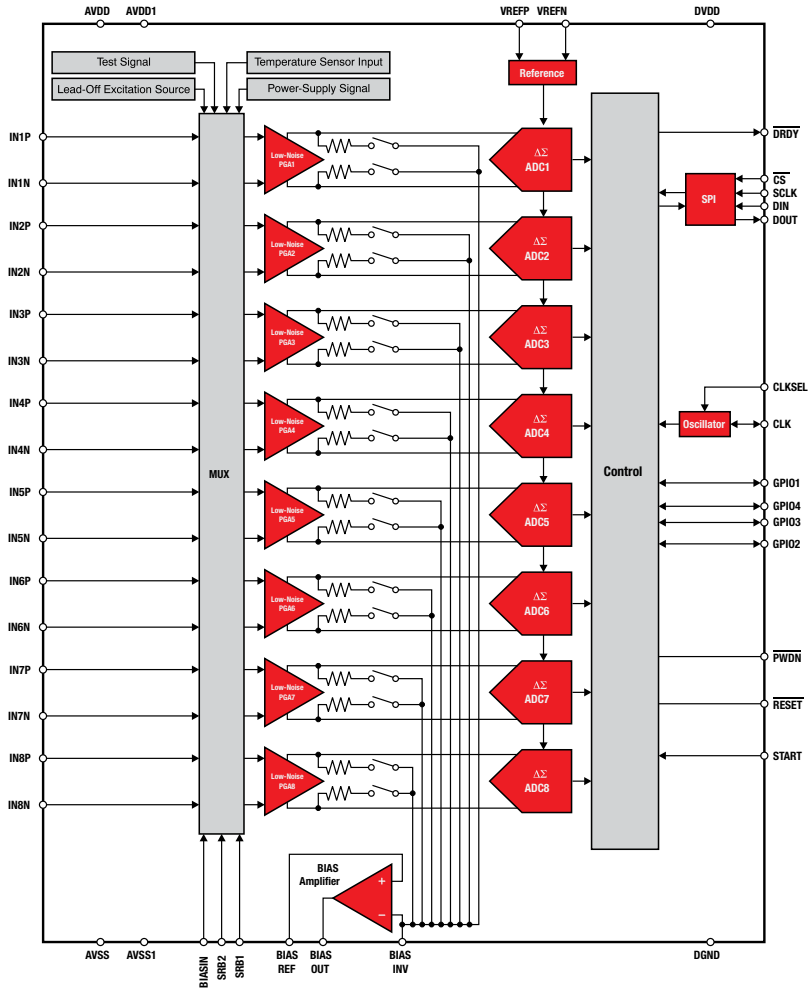
Applications

- Electroencephalography (EEG)
- Bispectral index studies (BIS)
- Evoked audio potential (EAP)
- Sleep study monitoring
- High-precision, simultaneous, multichannel signal acquisition up to 16kSPS

The ADS1299 drastically reduces printed circuit board space while improving performance and system reliability. Due to the extremely low input-referred noise of the ADS1299, it allows for direct interface to EEG bio-potential signals. The ADS1299 enables reliable and precise acquisition of minute extra-cranial biopotential signals even in the presence of large EMI signals.

Before such a low input-referred noise option existed, designers would have to discretely lay out ICs to accommodate an EEG signal, due to the signal amplitude only being 10µV-100µV. In a typical 32-electrode EEG system, about 149 ICs would have to be used to realize the full analog signal chain. With ADS1299, only four of the ADS1299 devices would have to be used, resulting in a 97% reduction in overall ICs used, making it the only one-chip solution for the EEG signal chain.

This fact, combined with the easy-to-use SPI interface that allows for daisy-chaining, enables a fully realized analog signal chain that greatly reduces board complexity for EEG designers.



ADS1299 functional block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

2-Ch., 24-Bit Fully Integrated ADC for Medical Instrumentation and Sports and Fitness Applications

ADS1292

Get samples and datasheets at: **www.ti.com/sc/device/ads1292**

Key Features

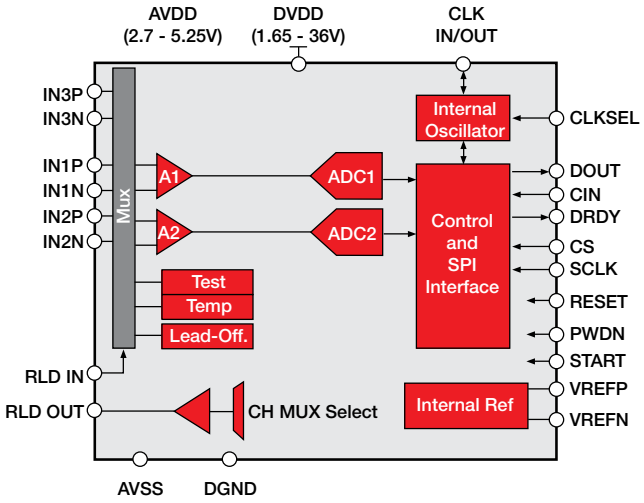
- Fully integrated ECG solution
- Optimized low noise PGA and 24-bit ADC
  - ADS1291: 1 channel
  - ADS1292: 2 channels
- Test signals, RLD amp, oscillator, reference
- Outstanding performance
  - Noise: less than 8µV p-p (150Hz BW, G=6)
  - CMRR: 105dB with G = 6
- Continuous lead off detection
- Low Power
  - Less than 350µW per channel
  - Standby mode: 160µW overall consumption

Applications

- Medical instrumentation:
  - 1- and 3-Lead ECG
  - Heart rate
  - AED
  - Holter
- Sports and fitness applications
  - Chest straps
  - Work-out equipment
  - Wrist watches

An ADS1292 solution takes up 92% less PCB space, consumes 94% less power, and uses 92% fewer components compared to a discrete implementation of a 2-channel Holter. Similarly, an ADS1291 solution takes up 52% less PCB space, 89% lower power consumption, and 75% fewer components over a discrete implementation.

Designers interested in creating a complete line of biopotential measurement products now have a family of devices to meet their needs from low lead count heart rate monitors (ADS1291) to 12-lead ECG systems (ADS1298).



ADS1292 functional block diagram.

Alternative Solutions

Device	Resolution	No. of Input Chs.	Respiration	Input-Referred Noise (μV_{pp})	Price*
ADS1298	24-bit	8	No	3	23.95
ADS1298R	24-bit	8	Yes	3	23.95
ADS1198	16-bit	8	No	12.2	14.35
ADS1296	24-bit	6	No	3	17.95
ADS1296R	24-bit	6	Yes	3	17.95
ADS1196	16-bit	6	No	12.2	11.35
ADS1294	24-bit	4	No	3	11.95
ADS1294R	24-bit	4	Yes	3	11.95
ADS1194	16-bit	4	No	12.2	7.80
ADS1293	24- bit	3	No	10	5.5
ADS1292	24-bit	2	No	8	3.50
ADS1292R	24-bit	2	Yes	8	4.50
ADS1192	16-bit	2	No	24	2.50
ADS1291	24-bit	1	No	8	2.00
ADS1191	16-bit	1	No	24	1.50

**Suggested resale price in U.S. dollars in quantities of 1,000.*

*New products are listed in **bold red.***

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Low Power, 3-Channel, 24-Bit Analog Front End for Biopotential Measurements

ADS1293

Get samples and datasheets at: **www.ti.com/sc/device/ads1293**

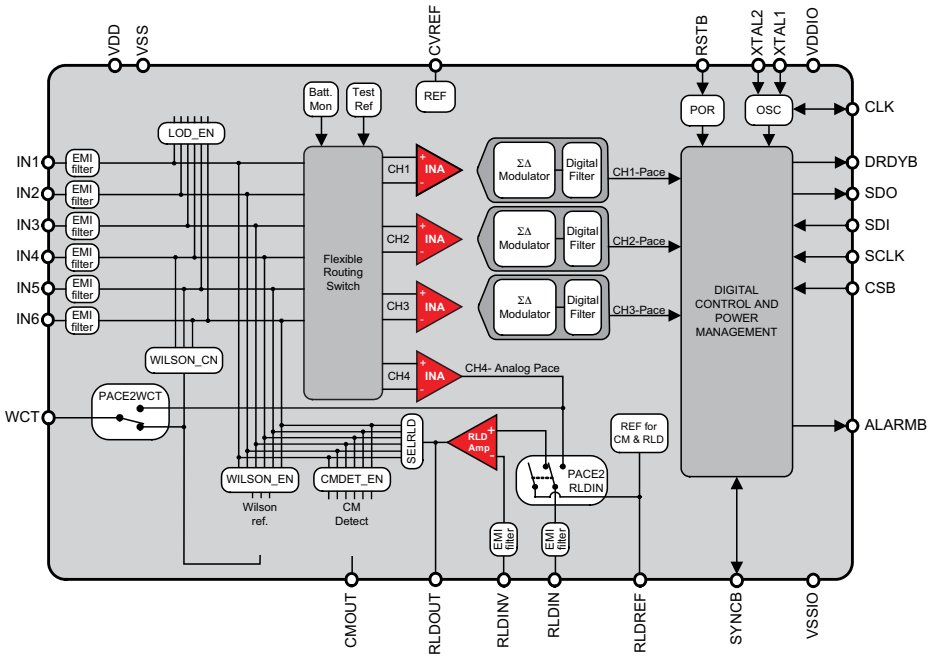
Key Features

- 3 High Resolution Digital ECG Channels with Simultaneous Pace Output
- EMI Hardened Inputs
- Low Power: 0.3mW/channel
- Input-Referred Noise: 10µVpp (40Hz BW)
- Input Bias Current: 100pA
- Data Rate: Up to 25.6kSPS
- Differential Input Voltage Range: ±400mV
- Analog Supply Voltage: 2.7V to 5.5V
- Digital I/O Supply Voltage: 1.65V to 3.6V
- Right Leg Driver Amplifier
- AC and DC Lead-Off Detection
- Wilson and Goldberger Terminals
- ALARM Pin for Interrupt Driven Diagnostics
- Battery Voltage Monitoring
- Flexible Power-Down and Standby

Applications

- Portable 1/2/3/5/6/7/8/12-Lead ECG
- Patient vital sign monitoring: holter, event, stress, and telemedicine
- Automated External Defibrillator
- Sports and fitness (heart rate and ECG)

The ADS1293 is an integrated three-channel analog front end that provides very low power consumption with low noise. The ADS1293 delivers a solution that can extend battery life, simplify product design and improve overall performance. The ADS1293 incorporates all features commonly required in portable, low-power medical electrocardiogram (ECG), sports, and fitness applications. With high levels of integration and exceptional performance, the ADS1293 enables the creation of scalable medical instrumentation systems from one to twelve channels at significantly reduced size, power and overall cost.



ADS1293 block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

High-Performance, Low-Power, Fixed-Point Digital Signal Processor

TMS320C5515

Get datasheets, samples and technical documents at: **www.ti.com/sc/device/tms320c5515**

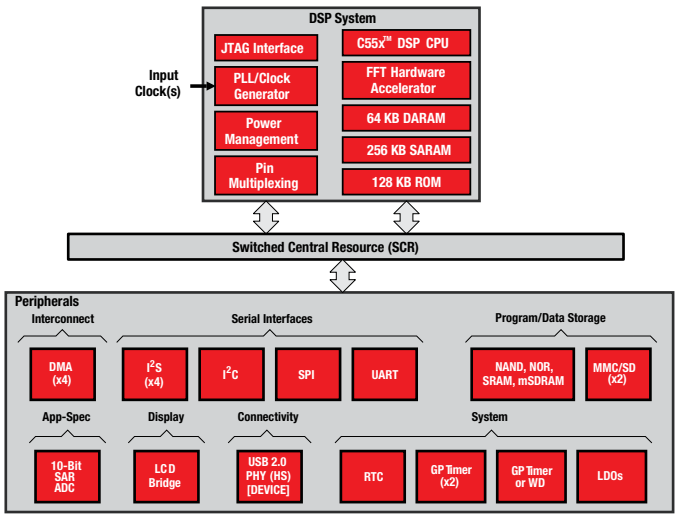
Key Features

- 320K bytes zero-wait state on-chip RAM, composed of:
  - 64K bytes of dual-access RAM (DARAM), 8 blocks of 4K × 16-bit
  - 256K bytes of single-access RAM (SARAM), 32 blocks of 4K × 16-bit
- 128K bytes of zero wait-state on-chip ROM (4 blocks of 16K × 16-bit)
- 4M × 16-bit maximum addressable external memory space (SDRAM/mSDRAM)
- 16-/8-bit external memory interface (EMIF)
- Direct memory access (DMA) controller

Applications

- Industrial controls
- Portable medical devices
- Wireless audio devices

The TMS320C5515 fixed-point DSP is based on the TMS320C55x™ DSP generation CPU processor core. The C55x™ DSP architecture achieves high performance and low power through increased parallelism and total focus on power savings. The CPU supports an internal bus structure that is composed of one program bus, one 32-bit data read bus and two 16-bit data read buses, two 16-bit data write buses, and additional buses dedicated to peripheral and DMA activity. These buses provide the ability to perform up to four 16-bit data reads and two 16-bit data writes in a single cycle.



TMS320C5515 block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Mixed-Signal Microcontroller

MSP430F6638

Get datasheets, samples and technical documents at: **www.ti.com/sc/device/msp430f6638**

Key Features

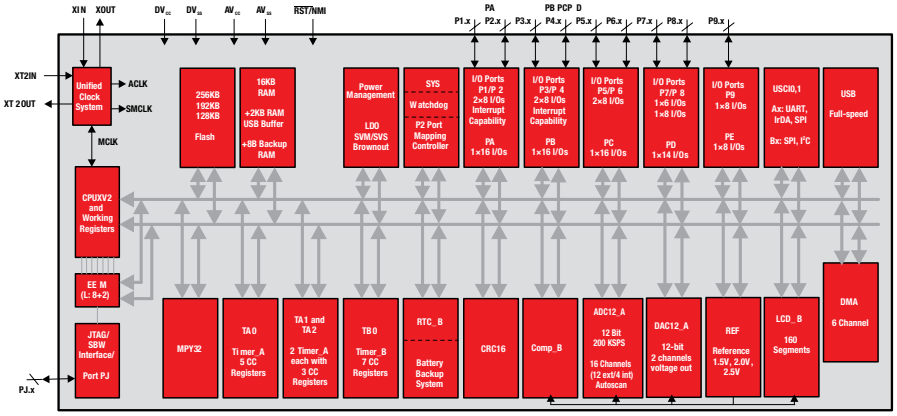
- Low supply voltage range, 1.8V to 3.6V
- Ultra-low power consumption
- Wake-up from standby mode in < 5µs
- 16-bit RISC architecture, extended memory, up to 20-MHz system clock
- Flexible power management system
- Unified clock system
- 16-bit timer TA0, Timer_A with five capture/compare registers
- 16-bit timer TA1, Timer_A with three capture/compare registers

Applications

- Analog and digital sensor systems
- Digital timers
- Hand-held meters
- Thermostats

The Texas Instruments MSP430™ family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low power modes is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 5µs.

The MSP430F663x series are microcontroller configurations with four 16-bit timers, a high performance 12-bit analog-to-digital (A/D) converter, 12-bit digital to analog (D/A) converter, two universal serial communication interfaces (USCI), hardware multiplier, DMA, real-time clock module with alarm capabilities, comparator and USB 2.



MSP430F6638 functional block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Sitara™ ARM Microprocessor

AM1802

Get datasheets, samples and technical documents at: **www.ti.com/sc/device/am1802**

Key Features

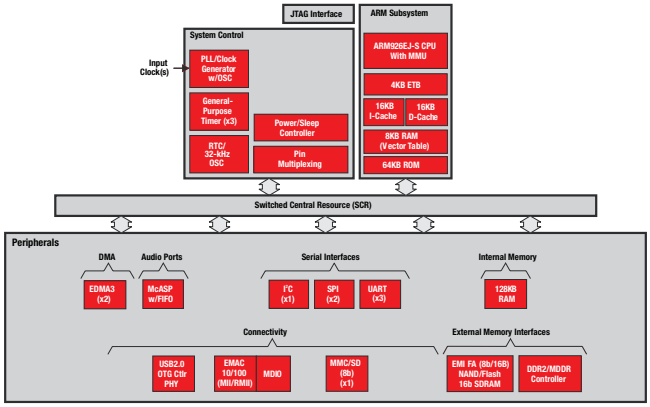
- ARM9 memory architecture
- Enhanced direct-memory-access controller 3 (EDMA3)
- Two external memory interfaces
- Two serial peripheral interfaces (SPI)
- Three configurable 16550 type UART modules
- Multiamedia card (MMC)/secure digal (SD) card interface with secure data I/O (SDIO)
- One master/slave integrated circuit
- One multichannel audio serial port
- 10/100 Mb/s Ethernet MAC (EMAC)

Applications

- Electrocardiogram (ECG)
- Pulse oximetry

The device is a low-power applications processor based on ARM926EJ-S™. The ARM926EJ-S is a 32-bit RISC processor core that performs 32-bit or 16-bit instructions and processes 32-bit, 16-bit, or 8-bit data. The core uses pipelining so that all parts of the processor and memory system can operate continuously.

The device enables OEMs and ODMs to quickly bring to market devices featuring robust operating systems support, rich user interfaces, and high processing performance life through the maximum flexibility of a fully integrated mixed processor solution.



AM1802 functional block diagram.

Digital Media Processor

DM3730

Get datasheets, samples and technical documents at: **www.ti.com/sc/device/dm3730**

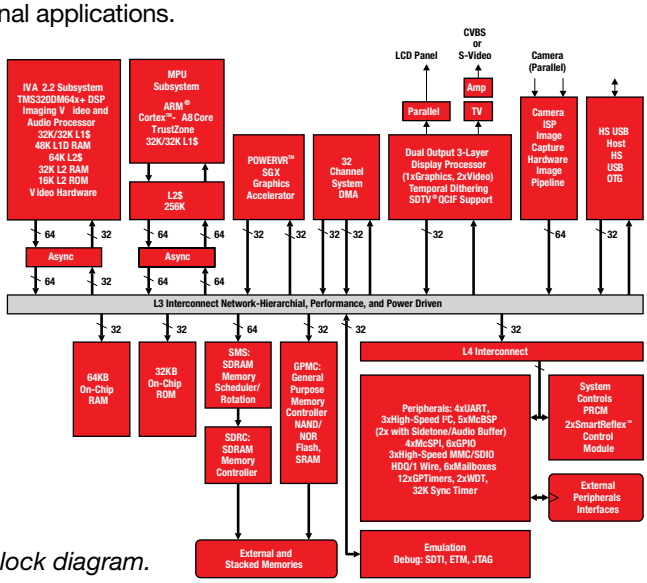
Key Features

- Compatible with OMAP™ 3 architecture
- ARM® microprocessor (MPU) subsystem
- High performance image, video, audio (IVA2.2™) accelerator subsystem
- Power SGX™ graphics accelerator

Applications

- Human interface
- Medical imaging
- Portable data terminals

The DM37x generation of high-performance, applications processors are based on the enhanced device architecture and are integrated on TI's advanced 45-nm process technology. This architecture is designed to provide best in class ARM and Graphics performance while delivering low power consumption. This balance of performance and power allow the device to support medical imaging, human interface and portable data terminal applications.



DM3730 functional block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Zero-Drift, Low-Offset, Single-Supply Op Amps

OPA334, OPA335

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/opa334** or **www.ti.com/sc/device/opa335**

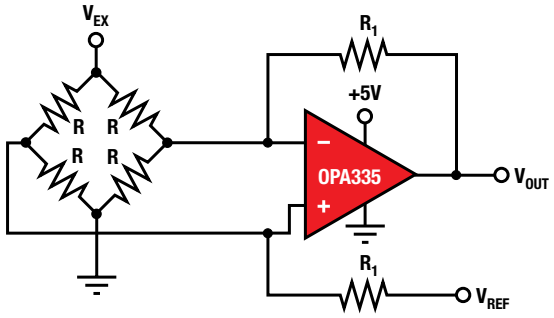
Key Features

- GBW: 2MHz
- Low offset voltage: 5µV (max)
- Zero drift: 0.05µV/°C (max)
- Quiescent current: 285µA
- EMI input filtered
- Shutdown available on OPA344
- Packaging: SOT23-5, SOT23-6, SO-8, MSOP-10 (dual)

Applications

- Transducer applications, such as pressure sensing
- Electronic weight scales
- Temperature measurement

The OPA334 and OPA335 CMOS op amps use auto-zeroing techniques to simultaneously provide very low offset voltage and near-zero drift over time and temperature. These high-precision amps offer high input impedance and rail-to-rail output swing.



OPA335 –5V supply bridge amplifier for high CMRR.

Low-Power Precision Instrumentation Amplifier

INA333

Get samples and datasheets at: **www.ti.com/sc/device/ina333**

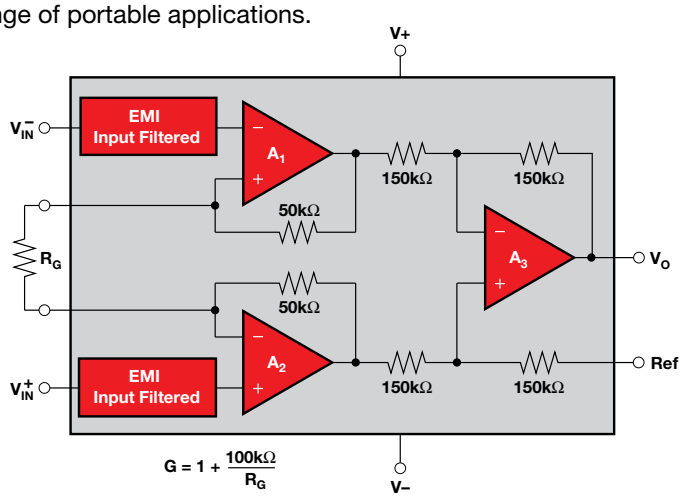
Key Features

- Low offset voltage: 20µV (max)
- Low drift: 50nV/°C
- Low input bias current: 200pA (max)
- Low noise: 50nV/$\sqrt{Hz}$
- Supply voltage: +1.8V to +5.5V
- Quiescent current: 50µA (max)
- EMI input filtered
- Packaging: MSOP-8, DFN-10

Applications

- Bridge amplifier
- Weigh scales
- Thermocouple amplifier
- RTD sensor amplifier
- Medical instruments
- Data acquisition

The INA333 is a low-power precision instrumentation amplifier offering excellent accuracy. A single external resistor sets any gain from 1 to 1000 and provides the industry-standard gain equation G = 1 + (100kΩ/R_G). With three op amps, low quiescent current, and operation with power supplies as low as +0.9V, it is ideal for a wide range of portable applications.



INA333 functional block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

3ppm/°C Drift, 0.05% Accurate, Low-Noise, Precision Series Voltage References
REF5020, REF5025, REF5030, REF5040, REF5045, REF5050, REF5010

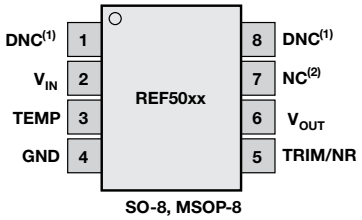
Get samples, datasheets and app reports at: **www.ti.com/sc/device/PARTnumber** (Replace **PARTnumber** with **ref5020**, **ref5025**, **ref5030**, **ref5040**, **ref5045**, **ref5050** or **ref5010**)

Key Features
- High accuracy: 0.05%
- Low temperature drift: 3ppm/°C (max)
- Very low noise: 3μV_{PP}/V
- High output current: ±10mA
- Wide supply range: 2.7V to 18V
- Industrial temperature range: –40°C to +125°C
- Packaging: SO-8, MSOP coming soon

Applications
- Test and measurement
- 16-bit data acquisition systems
- Medical and patient monitoring
- Industrial process control

The REF50xx brings a new level of precision to the TI series voltage reference line. Offering 3ppm/°C (max) drift and 0.05% initial accuracy and very low noise, the REF50xx is designed for industrial, medical and test applications that require performance over temperature.

Model	Voltage Out
REF5020	2.048V
REF5025	2.5V
REF5030	3.0V
REF5040	4.096V
REF5045	4.5V
REF5050	5V
REF5010	10V



REF50xx package diagram.

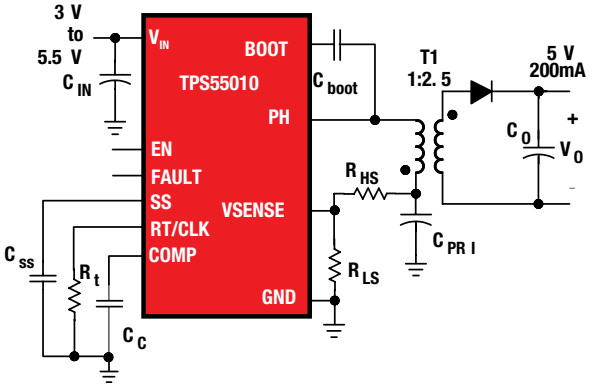
2.95V to 6V Input, 2W, Isolated DC/DC Converter with Integrated FETS
TPS55010

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/tps55010**

Key Features
- Isolated fly-buck topology
- Primary side feedback
- 100kHz to 2000kHz switching frequency
- Synchronizes to external clock
- Adjustable slow start
- Adjustable input voltage UVLO
- Open-drain fault output
- Cycle-by-cycle current limit
- Thermal shutdown protection
- 3mm x 3mm 16-pin QFN package

Applications
- Noise immunity in PLCs, data acquisition and measurement equipment
- Isolated RS-232 and RS-485 communication channels
- Powers line drivers, ISO amplifiers, sensors, CAN transceivers
- Floating supplies for IGBT gate drivers
- Promotes safety in medical equipment

The TPS55010 is a transformer driver designed to provide isolated power for isolated interfaces, such as RS-485 and RS-232, from 3.3V or 5V input supply. The device uses fixed frequency current mode control and half bridge power stage with primary side feedback to regulate the output voltage for power levels up to 2W. The switching frequency is adjustable from 100kHz to 2000kHz so solution size, efficiency and noise can be optimized. The switching frequency is set with a resistor or is synchronized to external clock using the RT/CLK pin. To minimize inrush currents, a small capacitor can be connected to the SS pin. The EN pin can be used as an enable pin or to increase the default input UVLO voltage from 2.6V.



TPS55010 functional block diagram.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

60mA Charge Pump Voltage Inverter with Fixed 250kHz Operation

TPS60403

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/tps60403**

Key Features

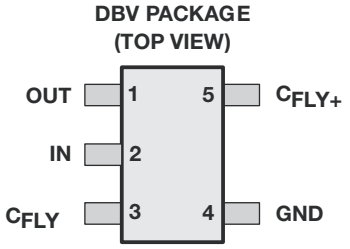
- Inverts input supply voltage
- Up to 60-mA output current
- Only three small 1-µF ceramic capacitors needed
- Input voltage range from 1.6V to 5.5V
- PowerSave-mode for improved efficiency at low output currents (TPS60400)
- Device quiescent current typical 65µA
- Integrated active Schottky-diode for start-up into load
- Small 5-pin SOT23 package

Applications

- Battery-operated equipment
- LCD bias
- Medical instruments
- Sensor supply in portable instruments

The TPS6040x is a family of devices that generate an unregulated negative output voltage from an input voltage ranging from 1.6V to 5.5V. The devices are typically supplied by a preregulated supply rail of 5V or 3.3V. Due to its wide input voltage range, two or three NiCd, NiMH, or alkaline battery cells, as well as one Li-Ion cell can also power them.

Only three external 1-µF capacitors are required to build a complete dc/dc charge pump inverter. Assembled in a 5-pin SOT23 package, the complete converter can be built on a 50mm2 board area. Additional board area and component count reduction is achieved by replacing the Schottky diode that is typically needed for start-up into load by integrated circuitry.



TPS60403 package.

800-mA Low-Dropout Adjustable and Fixed-Voltage Regulators

TLV1117, TLV1117-xx

Get samples, datasheets and application reports at: **www.ti.com/sc/device/tlv1117** or **tlv1117-xx**

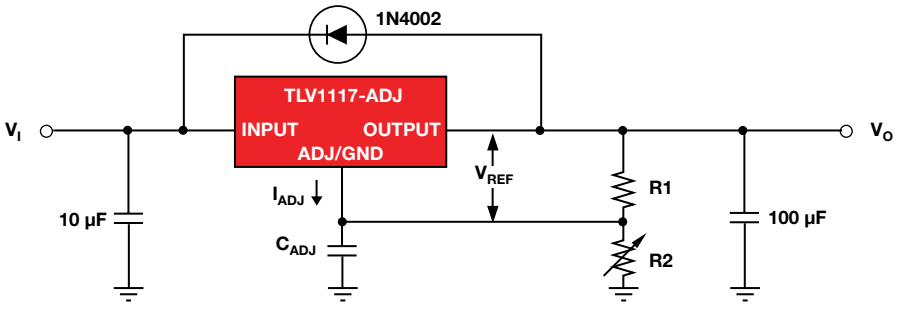
Key Features

- 1.5-V, 1.8-V, 2.5-V, 3.3-V, 5-V and adjustable-output voltage options
- Output current of 800mA
- Specified dropout voltage at multiple current levels
- 0.2% line regulation max
- 0.4% load regulation max

Applications

- Power supplies
- Set-top boxes
- Laptops

The TLV117 is a positive low-dropout voltage regulator designed to provide up to 800mA of output current. The device is available in 1.5-V, 1.8-V, 2.5-V, 3.3-V, 5-V and adjustable-output voltage options. All internal circuitry is designed to operate down to 1-V input-to-output differential. Dropout voltage is specified at a maximum of 1.3 at 800mA, decreasing at lower load currents. The TLV1117 is designed to be stable with tantalum and aluminum electrolytic output capacitors having an ESR between 0.2Ω and 10Ω. Unlike pnp-type regulators, in which up to 10 percent of the output current is wasted as quiescent current, the quiescent current of the TLV117 flows into the load, increasing efficiency.



V_{OUT} is calculated as: $V_{OUT} = V_{REF} (1 + \frac{R2}{R1}) + (I_{ADJ} \times R2)$

Because I_{ADJ} typically is 55 µA, it is negligible in most applications.

Application information.

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA118	Instrumentation Amp	110dB CMRR, 5nA (max) bias current, 50µV (max) offset	Wide BW at high gain, ±1.35V to ±18V supply	INA128, INA121
INA121	Instrumentation Amp	106dB CMRR, 4pA (max) bias current, 200µV (max) offset	Low input bias current	INA126
INA126	Instrumentation Amp	175µA/ch supply, 3µV/°C (max) drift, 250µV (max) offset	Precision low power, ±1.35V to ±18V supply	INA2126
INA128	Instrumentation Amp	120dB CMRR, 5nA (max) bias current, 50µV (max) offset	High CMRR, wide BW at high gain, ±2.25V to ±18V supply	INA129
OPA277	Op Amp	10µV offset, ±0.1µV/°C drift, 134dB open-loop gain	High precision, low drift, low power	OPA2277 (dual) OPA4277 (quad)
INA326	Instrumentation Amp	120dB CMRR (G = 100), 100µV (max) offset, 0.4µV/°C (max) drift	High CMRR, low cost, +2.7V to +5.5V	INA321, INA333
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA326, INA321
INA826	Instrumentation Amp	35ppm/°C (max) gain error drift, 250µA (typ) Iq	Cuts gain error and gain error drift in less than half compared to neares competitor while consuming 40% less power	
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA130	FET-Input Amplifier	20pA (max) bias current, 90dB (min) CMRR, 1MHz BW	Precision, low input bias, low power	OPA131, OPA137
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA334/5	Op Amp	2MHz, 5µV (max) offset, 0.05µV/°C (max) drift, 285µA	Provides very low offset voltage and near-zero drift over time and temperature; SOT23	OPA735, OPA333, OPA334
OPA336	Op Amp	125µV (max) offset, 1.5µV/°C drift, 20µA supply	micoPower, SOT23 package	OPA379
OPA378	Low Noise Precision Op Amp	0.1µV/°C Vos drift, 125µA, 900kHz, 0.4μV_{PP} (0.1Hz to 10Hz) 0.4µ V_{pp} (0.1Hz to 10Hz), 0.9MHz	Lowest noise, power, price, precision zero-drift option	OPA330, OPA333
OPA2378	Precision Op Amp	2.2V to 5.5V supply, 20µV voltage, 0.1µV/°C drift, 125µA quiescent current	Has excellent PSRR which makes it an ideal choice for applications that run direct from batteries without regulation	
THS4521/22/24	Low Power FDA	1.14mA quiescent current (typ), 4.6nV/$\sqrt{Hz}$ voltage noise, 2.5V to 5.5V supply	Low power, low noise enables high accuracy	
Data Converters				
ADS1258	Delta-Sigma ADC	16-channel, 24-bit, 125kSPS, 23.7kSPS/channel	Fastest multi-channel, delta-sigma ADC, measures all 16 inputs in <675µs	ADS1256, ADS1255, ADS8344
ADS1271/74/78	Delta-Sigma ADC	24-bit, 128kSPS, 8-channel, 111dB SNR	Simultaneous measurement, onboard decimation filter	
ADS1292R	ECG/EEG AFE	24-bit, 2 PGA, 2 ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1291, ADS1292, ADS1191, ADS1192
ADS1293	ECG/EEG AFE	24-bit, 3 PGA, 3 ADC, plus RLD and very low power	Very low power AFE. Flexible for 1, 2, 3, 5, 6, 7, 8, 12 lead battery powered applications.	ADS1292, ADS1294
ADS1298	ECG/EEG AFE	24-bit, 8 PGA, 8 ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1294, ADS1296, ADS1198, ADS1258
ADS8317	SAR ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL, differential input	Low power, small package, and wide supply range	ADS8326
ADS8326	Low-Power ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL	Small package, wide supply range	
ADS8331/32	SAR ADC	16-bit, 500kSPS, 4/8 channels, with serial interface	Mux out feature can be used to reduce system part count and overall cost	ADS8342
ADS8341/2/3/4/5	Serial Output ADC	16-bit, 4-/8-channel single-ended or 2-channel differential input, 2.7V to 5V single supply ADC	Easy to use	
ADS8519	High Volt. SAR ADC	16-bit, 250kSPS, 1.5LSB (max) INL, 92dB SNR	Single supply, high voltage inputs	ADS8515
DDC112	Charge-Digitizing ADC	Dual current input, 20-bit ADC, ±0.005% INL reading ±0.5ppm FSR	High precision, true integrating function	DDC114, DDC118, DDC232

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New products are listed in ***bold red****.*

Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF02	Precision V_{REF}	0.2% (max) initial accuracy, 10ppm/°C (max) drift, 1.4mA (max)	Excellent line/load regulation, low noise	REF5050
REF102	10V, Ultra Precision	0.05% (max) initial accuracy, 2.5ppm/°C (max) drift, 1.4mA (max)	Excellent stability and line/load regulation	REF5010
REF30xx	Low-Power, Low-Drift Ref.	50µA, 0.2% initial accuracy, 50ppm/°C max drift, ±25mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V		REF31xx, REF33xx, REF29xx
REF32xx	Ultra-Low-Drift Series Reference	100µA, 0.2% initial accuracy, 7ppm/°C max drift, ±10mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Improves system accuracy	
REF33xx	Very Low-Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF5010	10V, High-Precision, Very Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 10V	Improves system accuracy	REF102
REF50xx	High-Precision, Very Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Processors				
AM3354	Applications Processor	ARMR Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
DM3730	Digital Media Processor	Compatible with OMAP™ 3 architecture, ARM® microprocessor (MPU) subsystem, high performance image, video, audio (IVA2.2™) accelerator subsystem, power SGX™ graphics accelerator	Designed to provide best in class ARM and Graphics performance while delivering low power consumption.	
MSP430F20xx	Ultra-Low-Power 16-bit MCU	1KB/2KB Flash, 128B RAM, SPI+I^2C 16-bit MCU	8 ch. 12-bit ADC or 4 ch. 16-bit SD ADC, 4 x 4mm package	
MSP430F22x4	Ultra-Low-Power 16-bit MCU	8 to 32KB Flash, 512B/1KB RAM, SPI + I^2C + UART/LIN + IrDA	12 ch. 10-bit ADC, 2 operational amplifiers	
MSP430F23x0	Ultra-Low-Power 16-bit MCU	8 to 32KB Flash, 1KB/2KB RAM, SPI + I^2C + UART/LIN + IrDA	Analog comparator, HW multiplier	
MSP430F41x	Ultra-Low-Power 16-bit MCU	4 to 32KB Flash, 256B to 1KB RAM, SVS, 96 segment LCD	Analog comparator	
MSP430F42x	Ultra-Low-Power 16-bit MCU	8 to 32KB Flash, 256B to 1KB RAM, SPI + UART, SVS, 128 segment LCD	3 x 16-bit SD ADC	
MSP430F42x0	Ultra-Low-Power 16-bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC	
MSP430F43x	Ultra-Low-Power 16-bit MCU	16 to 32KB Flash, 512B/1KB RAM, SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, analog comparator	
MSP430F44x	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 1KB/2KB RAM, 2x SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, HW multiplier	
MSP430F47xx	Ultra-Low-Power 16-bit MCU	60KB Flash, 256B RAM, (4) USCI, 160 segment LCD	(4) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F241x	Ultra-Low-Power 16-bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, temp. sensor	8 ch. 12-bit ADC, analog comparator, HW multiplier	
MSP430F261x	Ultra-Low-Power 16-bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, DMA, temp. sensor	Analog comparator, 2 ch. 12-bit DAC, 8 ch. 12-bit ADC, HW multiplier	
MSP430F471xx	Ultra-Low-Power 16-bit MCU	120KB Flash, 8KB RAM, (4) USCI, DMA 160 segment LCD	(7) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F54xxA	Ultra-Low-Power 16-bit MCU	128 to 256KB Flash, 16KB RAM, (4) USCI, PMM, DMA, temp. sensor	16 ch. 12-bit ADC, analog comparator, RTC, internal voltage regulator for power optimization	
MSP430F6638	Ultra-Low-Power 16-bit MCU	1.8V to 3.6V low supply voltage range, wake-up from standby mode in > 5µs, unified clock system	This device is optimized to achieve extended battery life in portable measurement applications.	
MSP430FG42x0	Ultra-Low-Power 16-bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC, 2 integrated op amps	

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Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
MSP430FG43x	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD	12 ch. 12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amp, HW multiplier	
MSP430FG47x	Ultra-Low-Power 16-bit MCU	32 to 60KB Flash, 2KB RAM, SPI + I^2C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
TMS320C5000™	DSP	Power efficient, high performance		
TMS320F2802x/3x Piccolo™	32-Bit Microcontroller	Up to 60MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F283x Delfino™	32-Bit Floating-point Microcontroller	Up to 300MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
Linear Regulators				
LP2950x	100-mA Low-Dropout Adjustable and Fixed-Voltage Regulators	Wide input voltage range up to 30V. Rated output current of 100mA. Low dropout: 380 mV typ. Low quiescent current 75µA (typ)	Easy-to-use with wide input voltage range and low dropout	LP2951x
LP2981x	100-mA Ultra-Low-Dropout Fixed Regulators with Shutdown	Output tolerance of 0.75% or 1.25%. Ultra-low dropout, 200mV (typ). Low quiescent current. Shutdown current: 0.01µA (typ)	Ultra-low dropout, low quiescent current, shutdown and small packaging	
LP2985x	150 mA Low-Noise Low-Dropout Fixed Regulators with Shutdown	Output tolerance of 1% or 1.5%. Ultra-low dropout 280 mV (Typ). Shutdown current 0.01mA (Typ). Low noise 30μV_{RMS}	Low dropout, low quiescent current, shutdown, low-ESR capacitor-friendly, low noise and small packaging	
TL750x	750-mA and 150-mA Low-Dropout Fixed-Voltage Regulators	Very low dropout voltage, less than 0.6V at 150mA or 750mA. Very low quiescent current. 60-V load-dump protection	Very low drop out voltage with extremely low quiescent current	TL751x
TLV1117	800-mA Low-Dropout Adjustable and Fixed-Voltage Regulators	1.5-V, 1.8-V, 2.5-V, 3.3-V, 5-V and adjustable-output voltage options. Output current of 800mA.	Very efficient and stable	LM317, TL431, TLV431, TLVH431, TLVH432, UA7805
TPS2051C	USB Power Switch	USB compliant power source, short circuit protection	USB switch accurate limit and fast turn off	TPS2065C
TPS2511	USB Switch with BC1.2 Charging Control	USB compliant and able to handshake with BC1.2 compliant clients	USB switch allows charging of peripheral devices with no uC support	TPS2540/40A/41/41A/43
TPS2552/3	Precision Adjustable USB Power Switch	Family of precision adjustable current limit devices	Accurate limits provide greater protection and require less supply margining	TPS2554/5/6/7
TPS3839	Supervisor and Reset IC	Ultra-low 150nA, ultra-small voltage supervisor	monitors voltage rails and provides high accuracy reset	TPS3808
TPS7A3001	Low-Noise Negative Voltage (–36V) LDO	V_{IN} –3V to –36V, –200mA, ultra-low noise, High PSRR, low-dropout linear regulator	Low-noise negative power rails for sensitive analog components	

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Electrocardiogram (ECG)/Portable ECG and Electroencephalogram (EEG)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Linear Regulators (Continued)				
TPS7A4700	Lowest-Noise 1A High Voltage (36V) LDO	Low noise (3µVrms), 1A, high voltage low-dropout linear regulator	Low-noise power rails for sensitive analog components	TPS7a3301
TPS7A4901	Low-Noise High Voltage (36V) LDO	V_{IN} 3V to 36V, 150mA, ultra-low noise, high PSRR, low-dropout linear regulator	Low-noise power rails for sensitive analog components	
TPS717xx	Low-Noise Single-Channel LDO	High bandwidth, very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS799xx
TPS75005	PMU	Dual, 500mA low-dropout regulators and triple voltage rail monitor	Core and I/O voltage rails in one LDO	
Comparators				
LM339	Quad Differential Comparator	Wide supply range: 2V to 36V. Low supply current drain independent of supply voltage: 0.4mA typ per comparator. Low input bias and offset parameters	Very accurate and easy-to-use	
LM393	Dual Differential Comparator	Wide supply range: 2V to 36V. Low supply current drain independent of supply voltage: 0.4mA typ per comparator. Low input bias and offset parameters	Very accurate and easy-to-use	LM311, LMV331, LMV393
RF Transceivers				
CC1120	Sub-1GHz RF Transceiver	Industry leading RF blocking and selectivity: 65dB adjacent channel rejection at 12.5kHz offset 90dB blocking. High output power (up to +16dBm) and excellent sensitivity (–123dBm @1.2kbps). WaveMatch; Advanced DSP sync detector with high sensitivity and strong noise immunity.	The most robust RF transceiver on the market. Reliable communication in presence of RF interference. Up to 139dB RF link budget. More reliable links, no false sync detects in noise. Enables RF sniff mode with <3mA current consumption.	
CC2520	2.4GHz ZigBee®/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temperature range; AES-128 security module	Reliable RF link with interference present; 400m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, High throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, High throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC2530/31	Second Gen. System-on-Chip Solution for 2.4GHz IEEE 802.15.4/ RF4CE/ZigBee®	Excellent RX sensitivity, low power, easy to use development tools	RF design system-on-chip for quick time to market. Provides a robust and complete ZigBee® USB dongle or firmware-upgradable network node.	CC2590/91, CC2530ZNP
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class system-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	DLP® Pico™
Toolkits				
ADS1298ECGFE-PDK	Reference design for the ADS1298	Easy-to-use evaluation software, built-in analysis tools including oscilloscope, FFT, and histogram displays, flexible input configurations, optional external reference circuits	The ADS1298ECG FE can be used with a variety of patient simulators and allows the user to take advantage of the flexible input multiplexer which can be independently connected to the internally-generated signals for test, temperature, and lead-off detection.	

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New products are listed in ***bold red****. Preview products are listed in* ***bold blue****.*

Pulse Oximeter

Overview

The pulse oximeter measures blood oxygenation by sensing the infrared and red-light absorption properties of deoxygenated and oxygenated hemoglobin. The oximeter is comprised of a sensing probe that attaches to a patient's ear lobe, toe or finger and is connected to a data acquisition system for the calculation and display of oxygen saturation level, heart rate and blood flow.

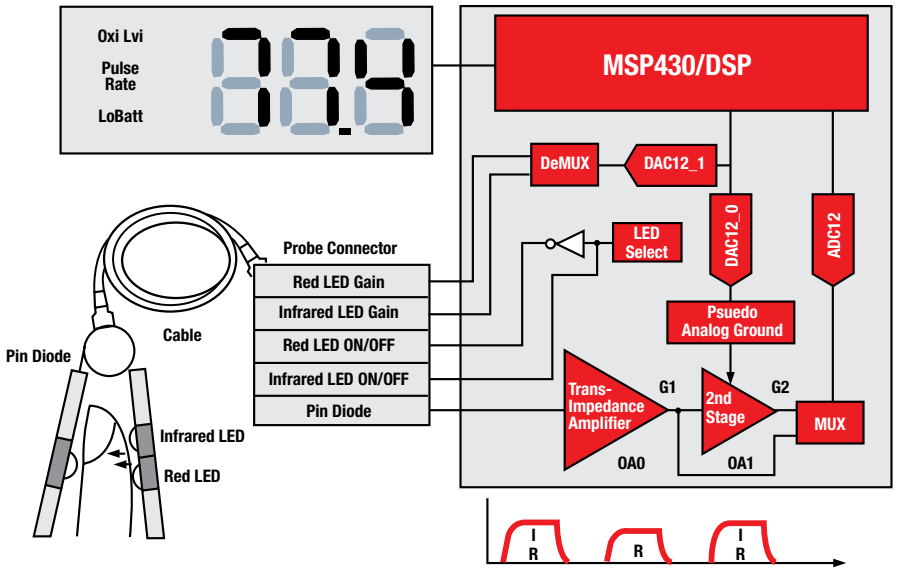
Light sources, typically light-emitting diodes (LEDs), shine visible red and infrared light. Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red light. Highly oxygenated hemoglobin allows more red light to pass through and absorbs more infrared light.

The oximeter senses and calculates the amount of light at those wavelengths proportional to the oxygen saturation (or desaturation) of the hemoglobin. The use of light in the absorbency measurement requires the designer to have a true "light-to-voltage" conversion using current as the input signal.

Amplifiers and Processors

The classic resistor-feedback transimpedance amplifier and capacitor-feedback switched integrator are suitable for pulse oximetry applications. In either amplifier configuration, the resulting output voltage is read by an analog-to-digital converter and serialized for the MSP430™ microcontroller or TMS320™ DSP for processing.

Processor selection should be based on signal-processing needs. TI has a wide variety of MSP430 products offering up to 25MIPS performance and extensive mixed-signal integration. For mid-range to high-end systems requiring much higher digital signal performance for enhanced signal conditioning and processing, low-power DSP processors such as C55x™ can be used. These processors offer higher than 100MIPS at very low power.



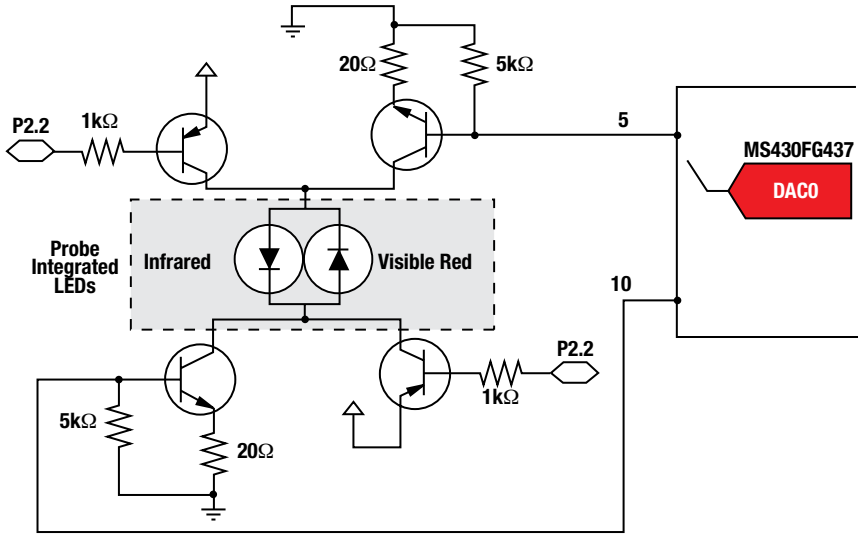
Apart from the MCU and four transistors, only passive components are needed for this design.

Low-End Portable Pulse Oximeter

For low-end designs, TI's highly integrated MSP430FG437 reduces the number of external components. The design of a non-invasive optical pulse oximeter using the MSP430FG437 microcontroller (MCU) consists of a peripheral probe combined with the MCU displaying the oxygen saturation and pulse rate on an LCD glass. In this application, the same sensor is used for heart-rate detection and pulse oximetry.

The probe is placed on a peripheral point of the body, such as a fingertip, an ear lobe or the nose. The probe includes two LEDs — one in the visible red spectrum (660nm) and the other in the infrared spectrum (940nm). The percentage of oxygen in the body is determined by measuring the intensity from each frequency of light after it is transmitted through the body. Then, the ratio between these two intensities is calculated.

The diagram below demonstrates the implementation of a single-chip, portable pulse oximeter using the ultra-low-power capability of the MSP430 MCU.



LED drive circuit.

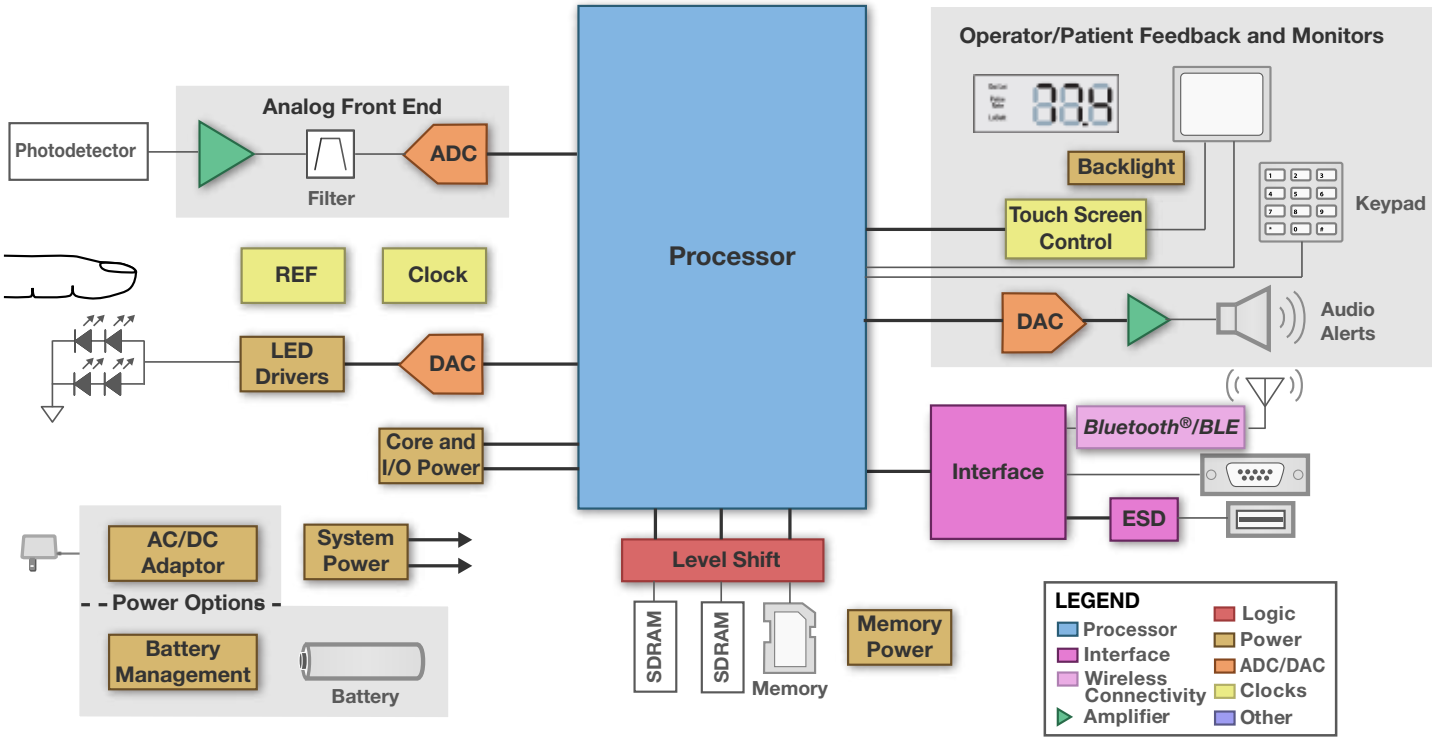
Pulse Oximeter

Because of the high level of analog integration, the number of external components is kept to a minimum. Keeping ON time to a minimum and power cycling the two light sources also reduces power consumption.

Mid-Range and High-End Applications

For mid-range and high-end applications where higher performance and higher measurement accuracy are necessary, there is a need for higher-performance processors and high-precision analog components that provide lower system power.

For example, several sources of interference such as neon lamps, UV lamps and other light emitters may influence the optical path between LEDs and the photoreceiver, affecting measurement accuracy. There could also be signal distortion caused by motion that occurs while the reading is taken. Sophisticated DSP technology can be applied to eliminate or reduce these effects and extract the vital signal of interest. Often, these DSP technologies require high-sample-rate signal-processing operations such as demodulation, digital filtering, decimation, and frequency-domain analysis, which can be efficiently mapped to a C55x™ low-power digital signal processor.



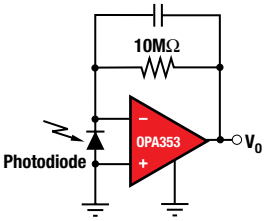
Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Pulse oximeter system block diagram.

Pulse Oximeter

Signal Acquisition Challenges

The resistor-feedback amplifier circuit is the most common bioelectric transimpedance circuit. With the amplifier used in the inverting configuration, the light shining on a photodiode produces a small current that flows to the amplifier summing junctions and through the feedback resistor. Given the very large feedback resistor value, this circuit is extremely sensitive to changes in light intensity. For example, an input light signal of just 0.001µW can produce a full-swing output.



Depending on design requirements, it can be very useful to achieve output swing down to or below ground. The auto-zero transimpedance amplifier configuration shown in Figure A at right allows swing to ground, while the one in Figure B allows swing very close to ground. A pull-down resistor tied to –5V allows swing slightly below ground to minimize errors as the output gets very close to 0V.

TI's OPA380 is a monolithic combination of the high-speed OPA355 and auto-zero OPA335 amplifiers. It offers a 90MHz gain-bandwidth product and performs well as a 1MHz transimpedance amplifier with extremely high precision (25µV maximum offset and 0.1µV/°C maximum drift).

Depending on design requirements, the switch integrator can be a very effective solution. TI's IVC102 does not have the thermal noise of a feedback resistor and does not suffer from stability problems commonly found in transimpedance amps with a large feedback resistor.

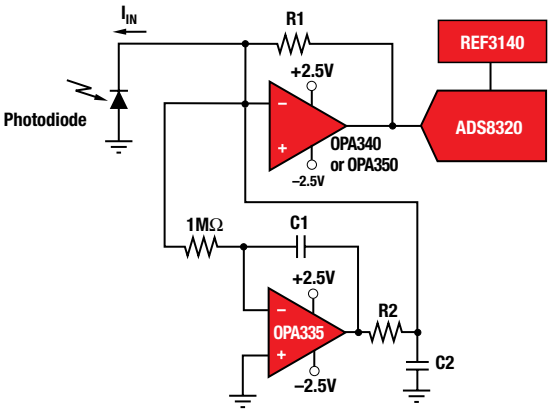
Using one photodiode with two IVC102s eliminates dark current and ambient light errors, since errors common to both can be subtracted.

Additionally, IVC203 allows for synchronized sampling at an integer multiple of the AC line frequency, giving extremely high noise rejection. Transimpedance gain can be easily changed by extending or shortening integration time with switch S2.

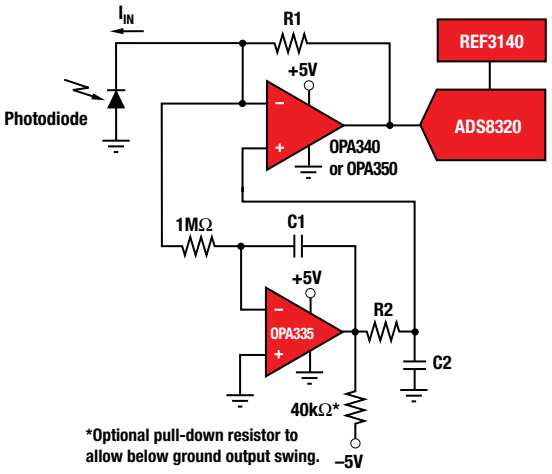
Transimpedance Amplifier Requirements

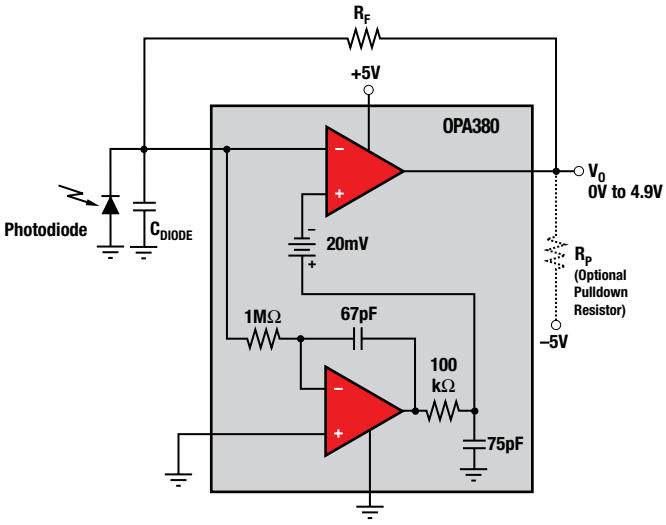
- Low input bias current over temperature range of interest
- Low input capacitance relative to photodiode capacitance
- High gain-bandwidth product
- Low voltage noise
- For maximum precision, low offset drift over temperature
- For single-supply systems:
  - Rail-to-rail input (including OV) and output if operating the photodiode in photovoltaic (zero-bias) mode
  - Rail-to-rail output only if operating the photodiode in photoconductive mode (biased)
  - Shutdown and/or low supply current if battery-powered system

A. Dual Supply



B. Single Supply





Pulse Oximeter

Design Hints

A small (<1pF) capacitor in the feedback loop (C_F) controls gain-peaking caused by diode capacitance. Noise (voltage-output fluctuation) is caused by resistor noise, amplifier and current noise, and environmental noise pickup (e.g., 50Hz or 60Hz line noise). To minimize noise in the circuit, the designer should choose a low-noise amplifier, select the largest practical feedback resistor, RF shield the amplifier inputs, include low-pass filtering and use good PCB layout techniques.

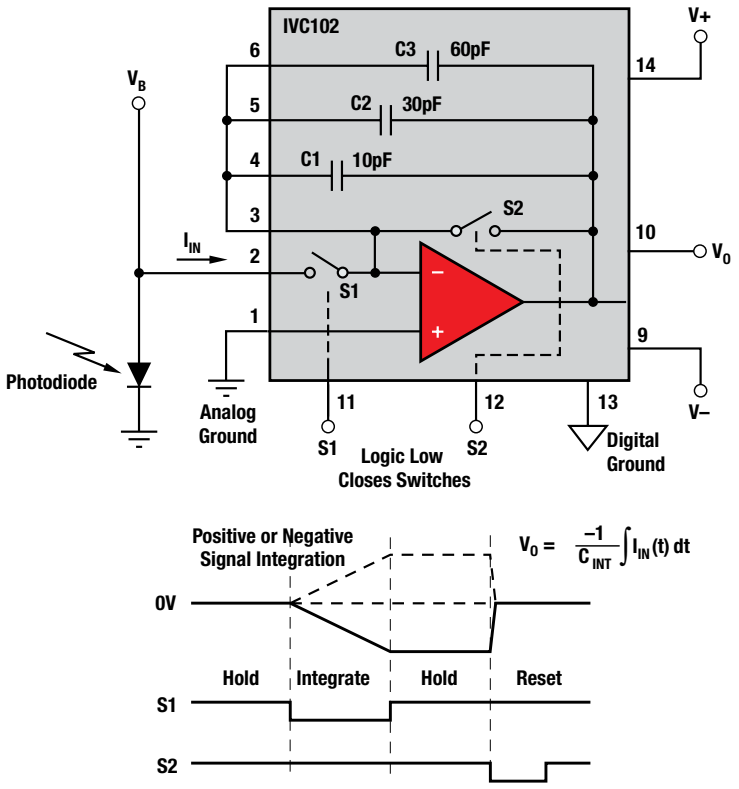
If the photodiode shunt resistance is much larger than that of the feedback resistor, offset voltage is not significant. If offset voltage stability is paramount, an auto-zero solution including the OPA335 is best.

To achieve the highest precision levels, system designers should choose the OPA380. Designed to meet exacting transimpedance application requirements, the OPA380 provides an unbeatable combination of speed (85MHz GBW over 1MHz transimpedance bandwidth) and precision (25µV maximum offset, 0.1µV/°C drift and low 1/f noise). A discrete alternative is to use the OPA365, OPA350, or OPA355, adding the OPA335 in the integrators-stabilized transimpedance configuration for circuits requiring low offset and drift. Adding the OPA335 integrator to a basic transimpedance amplifier will also reduce its very low frequency noise.

Mid-Range Solution Advantages

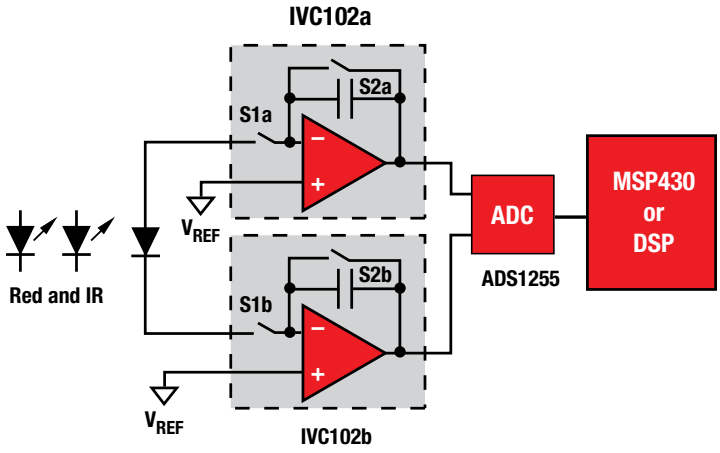
- Single-chip solution
- High resolution
- Low noise
- Wide input range by adjustable integration time
- No need for DC corrections of the diode current

Note: “Pulse Oximeter Design using MSP430FG43x” (slaa274)
www-s.ti.com/sc/techlit/slaa274



High-End Solution Advantages

- Very high resolution
- High noise immunity due to differential input
- High noise immunity due to synchronization on AC supply possible
- High noise immunity due to free access on integration and reset switches by software
- No need for DC correction of the diode currents
- Huge input range can be covered (>24-bit) due to free programmable integration times



High-end solution block diagram.

Pulse Oximeter

Integrated Solution for Photometry (Clinical SpO2)

AFE4490

Get samples and datasheets at: **www.ti.com/product/AFE4490**

Key Features

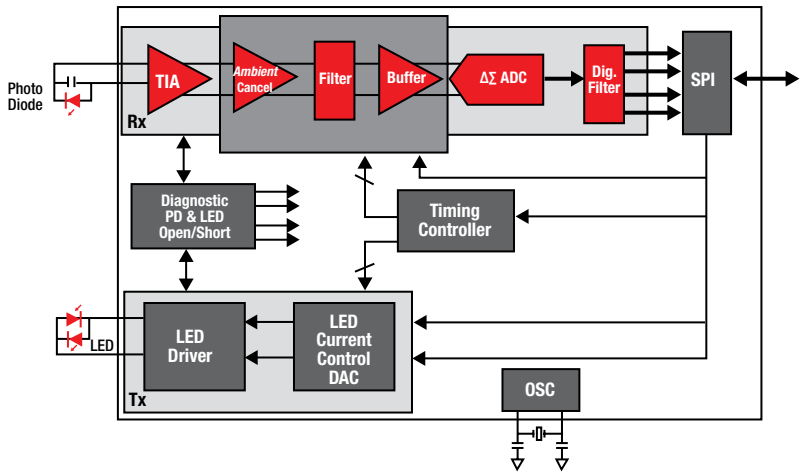
- Transmitter
  - H-bridge LED driver
  - Dynamic range >105dB
  - LED current 150mA (with 8-bit current setting)
  - LED ON (programmable 50uS to 250uS
  - LED current reference (Independent RED and IR)
  - LED open/short detect
- Receiver
  - Pulse frequency 625Hz to 100Hz
  - 1uA photodiode current (>13 noise free bits)
  - 5uA photodiode current (>13.5 noise free bits)
  - Low power receiver (<4mW at 2.2V)
  - Receiver sample time 50uS to 250uS
  - Programmable trans-impedance Amp with 7 resistor settings
  - Independent settings for RED and IR paths
  - Digital ambient estimation and subtraction (separate RED/IR ambient values)
  - Photodiode open/short detect

Other Features

- Flexible pulse sequencing and timing
- Cable on/off detect
- Supplies (Rx: 2.2V to 3.6V, Tx: 5V)

The AFE4490 is a fully-integrated analog front-end (AFE) that is ideally suited for pulse-oximeter applications. The device consists of a low-noise receiver channel with a 22-bit analog-to-digital converter (ADC), an LED transmit section, and diagnostics for sensor and LED fault detection. The AFE4490 is a very configurable timing controller. This flexibility enables the user to have complete control of the device timing characteristics. To ease clocking requirements and provide a low-jitter clock to the AFE4490, an oscillator is also integrated that functions from an external crystal. The device communicates to an external microcontroller or host processor using an SPI™ interface.

This AFE4490 is a complete AFE solution packaged in a single, compact QFN-40 package (6mm × 6mm) and is specified over the operating temperature range of –40°C to +85°C.



AFE4490 block diagram.

Pulse Oximeter

1.1nV/√Hz Noise, Low-Power, Precision Op Amp
OPA211, OPA2211

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/opa211**

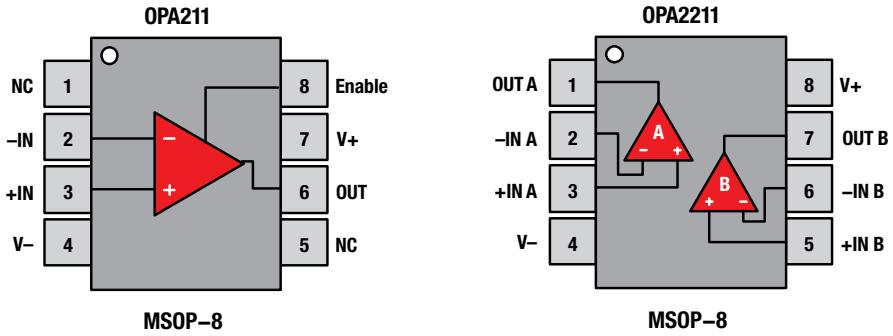
Key Features

- Input voltage noise: 80nV$_{PP}$, 0.1Hz to 10Hz
- Low offset voltage: 50µV (max)
- Low offset voltage drift: 0.15µV/°C (typ)
- Supply current: 3.6mA/ch
- Gain bandwidth product: 80MHz (G = 100)
- Slew rate: 27V/µs
- Supply range: ±2.25V to ±18V, +4.5V to +36V
- Output current: 30mA
- Unity gain stable
- Packaging: Tiny DFN-8, MSOP/SO-8

Applications

- Medical instruments
- Portable medical devices
- Ultrasound amplifiers
- Low-noise, low-power signal processing

The OPA211 series achieves very low 1.1nV/√Hz noise density with a supply current of only 3.6mA. It offers rail-to-rail output swing to maximize dynamic range. In precision data acquisition systems, the OPA211 provides <1µs settling time to 16-bit accuracy even for 10V output swings. By combining AC performance with only 50µV of offset and low drift over temperature, the OPA211 is able to drive fast, high-precision ADCs or buffer the outputs of high-resolution DACs.



Pin configurations.

Low Power Drivers
ULN2003LV, ULN2003V12

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/uln2003lv**

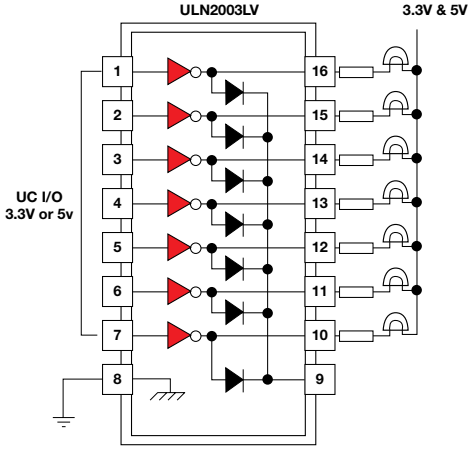
Key Features

- Compatible to 3.3V/5V micro-controllers and relays
- Very low input leakage and stand-by currents
- Low output VOL of 0.6V with internal free-wheeling diodes for inductive kickback protection
- Input pull-down resistor allows tri-state input drivers

Applications

- Relays and similar Inductive Drivers in Telecom, Consumer and Industrial applications
- Uni-polar Stepper Motor Driver
- Lamp and LED Displays
- Logic Level Shifter
- Logic Driver
- Constant current generator

The ULN2003 family of 7-channel Darlington transistor array features 7 low output impedance drivers that minimize on-chip power dissipation and support low voltage relay and inductive coil applications. The ULN2003 series supports 3.3V to 5V CMOS logic input interface thus making it compatible to a wide range of micro-controllers and other logic interfaces. The ULN2003 series features an improved input interface that minimizes the input DC current drawn from the external drivers.



ULN2003LV, ULN2003V12 functional block diagram.

Pulse Oximeter

Pulse Oximeter (PO or SpO2) Analog Front End Module for the C5515 PO or SpO2 Medical Development Kit

TMDXMDKPO8328

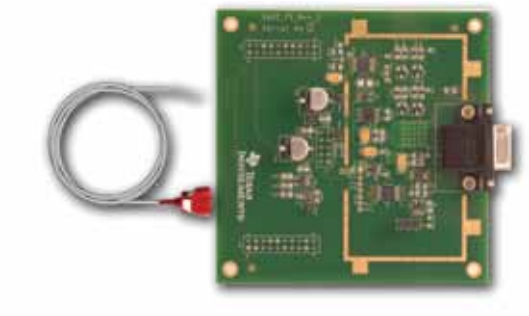
Get samples, datasheets and evaluation modules at: **www.ti.com/tmdxmdkpo8328**

Key Features

- PO AFE module key components
  - ADS8328: low power, 16-bit, 500ksps, analog-to-digital converter (ADC)
  - DAC7573: quad, 12-bit, low power, voltage output digital-to-analog converter DAC
  - OPA381: precision, low power, transimpedance amplifier (current to voltage converter)
  - REF5025: low noise, very low drift, precision voltage reference
- DS MDK system features
  - Based on industry's lowest power DSP processor – TMS320C5515
  - Display of oxygen level percentage ranging from zero to 100 percent
  - Display of pulse rate, ranging from 20 to 300
  - Real-time display of plethysmogram on PC
  - Sensor off detection
  - Common signal conditioning path for red and infrared signal

To reduce the time to market for medical device companies, TI has launched a set of medical application development tools with complete signal chain designs and software for electrocardiograms, digital stethoscopes, and pulse oximeter products. Each of the three medical development kits (MDKs) is comprised by purchasing an analog front-end (AFE) module with specific circuitry design optimized for each end product plus a TMS320C5515 DSP Evaluation Module (EVM) based on the industry's lowest power DSP – TMS320C5515. MDKs provide a great evaluation platform to help medical device manufacturers focus on product differentiation, like algorithm development and feature enhancement.

The TMDXMDKPO8328 Pulse Oximeter (PO or SpO2) Analog Front End (AFE) module consists of the PO AFE module, a processor board (C5505 DSP evaluation module), a set of collateral and C5505 based application sample code to implement the PO application. The PO MDK delivers a complete signal chain solution to enable PO developers to build a complete PO system quickly for evaluation and get to production faster.



Applications

- Pulse oximeters
- Patient monitoring

Pulse Oximeter

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
IVC102	Transimpedance Amp	Precision switched integrator	Reduces noise by averaging the input noise of the sensor, amplifier, and external sources	
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
LM6211	Low noise precision Op Amp	5V to 24V supply voltage range, 5.5nV/input referred voltage noise, 20MHz unity gain bandwidth, 400Hz 1/f corner frequency, 5.6V/µs slew rate, 1.05mA supply current, 5.5pF low input capacitance, 0.01% @ 1kHz, 600 total harmonic distortion, 25mA output short circuit current	Low noise op amp with very low input bias currents and a large output voltage swing	
LMV772	RRO Op Amp	Voltage noise f = 100Hz 12.5nV/√Hz, f = 10kHz 7.5nV/√Hz; rail-to-rail output swing RL = 600Ω 100mV from rail; 100dB open loop gain with RL = 2kΩI; VCM 0 to V±0.9V; supply current 550µA	Designed for precision, low noise, low voltage, and miniature systems	
LMV832	EMI hardened Op Amp	100dB open loop gain with RL = 2kΩ, 0 to V±0.9V VCM, 550µA supply current, 3.5MHz gain bandwidth	EMI hardened to minimize any interference, ideal for EMI sensitive applications	
LMV852	EMI hardened Op Amp	2.7V to 5.5V supply voltage, 0.4 mA supply current (per channel), 1 mV max Input offset voltage, 0.1pA input bias current, 8MHz GBW, 87dB EMIRR at 1.8GHz, 11nV/√Hz Input noise voltage at 1kHz, 4.5V/µs slew rate, rail-to-rail output voltage swing, 30mA output current drive	EMI hardened to minimize any interference, ideal for EMI sensitive applications	
OPA141	Precision Op Amp	10MHz, 6.5nV/√Hz, ±4.5V to ±18V, 1.8mA typical, FET input: I_B = 20pA max	Common mode voltage range includes GND	OPA827
OPA211/2211	Precision Op Amp	1.1nV/√Hz noise at 1kHz, ±2.25V to ±18V supply, 80MHz BW	Unity gain stable, RRO, wide supply range	OPA227, OPA827
OPA313	Micro-Power Op Amplifier	50µA/ch low IQ, 1.8 V to 5.5 V wide supply range, 25nV/√Hz at 1kHz, 1MHz gain bandwidth, 0.2pA input bias current, 0.5mV offset voltage, unity-gain stable, internal RF/EMI filter	Low-cost, general purpose, micro-power op amp with a robust design for ease-of-use	
OPA314	CMOS Amp	150µA/ch low IQ, 1.8V to 5.5V wide supply range, 14nV/√Hz at 1kHz low noise, 3MHz gain bandwidth, 0.2pA input bias current, 0.5mV offset voltage, unity-gain stable, internal RF/EMI filter	Low-power, general-purpose CMOS amplifiers with a robust design for ease-of-use	
LMV601	Low Cost CMOS Input Op Amp	200µA/ch low IQ, 1MHz gain bandwidth, 0.02pA input bias current, unit gain stable	Lowest-cost, micro-power general purpose CMOS amplifiers	
OPA333	Op Amp	10µV (max) low offset voltage, 0.05µV/°C (max) zero drift, 1.1µVPP 0.01Hz to 10Hz noise, 17µA quiescent current, single-supply operation, 1.8V to 5.5V supply voltage, rail-to-rail I/O, SC70 and SOT23 MicroSIZE packages	Simultaneously provide very low offset voltage (10µV max) and near-zero drift over time and temperature	
OPA334/5	Op Amp	2MHz, 5µV (max) offset, 0.05µV/°C (max) drift, 285µA	Provides very low offset voltage and near-zero drift over time and temperature; SOT23	OPA735, OPA333, OPA334
OPA335	Op Amp	5µV (max) low offset voltage, 0.05 µV/°C (max) zero drift, 285 µA quiescent current, single-supply operation, single and dual versions, shutdown, MicroSIZE packages	Simultaneously provide very low offset voltage (5µV max) and near-zero drift over time and temperature	
OPA336	Op Amp	125µV (max) offset, 1.5µV/°C drift, 20µA supply	micoPower, SOT23 package	OPA379
OPA350	Op Amp	500µV V_{OS}, 38MHz, 2.5V to 5V supply		
OPA353	MicroAmplifier™ Series	High speed, single supply, rail-to-rail		
OPA354	CMOS Single Op Amp	250MHz unity-gain bandwidth, 100MHz GBW wide bandwidth, 150V/µs high slew rate, 6.5nV/√Hz low noise, rail-to-rail I/O, > 100mA high output current, excellent video performance, 3pA low input bias current, 4.9mA quiescent current, thermal shutdown, 2.5V to 5.5V supply range, MicroSIZE and PowerPAD packages	Unity-gain stable, can drive large output currents	
OPA363	Op Amp	1.8V, high CMR, RRIO, shutdown		OPA364
OPA365	Zero-Crossover Op Amp	1.8V to 5.5V, 50MHz BW, 25V/µs slew rate, 0.0004% (typ) THD+N, 4.5nV/√Hz at 100kHz, RRIO	Zero-crossover, high speed, low input bias, low noise, RRIO	
OPA380	Transimpedance Amp	1MHz transimpedance bandwidth, 50pA (max) bias current, 25µV (max) offset voltage, 4 to 5 decades dynamic range, 0.1µV/°C (max) drift, 90MHz gain bandwidth, 7.5mA quiescent current, 2.7V to 5.5V supply range, single and dual versions, MSOP-8 MicroSIZE package	Excellent long-term VOS stability	

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New products are listed in ***bold red****.*

Pulse Oximeter

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers (Continued)				
OPA381	Transimpedance Amp	Over 250kHz transimpedance bandwidth, 5 decades dynamic range, 10nV/√Hz low voltage noise, 3pA bias current, 25µV (max) offset voltage, 0.1µV/°C (max) offset drift, 18MHz gain bandwidth, 800µA quiescent current, fast overload recovery, 2.7V to 5.5V supply range, single and dual versions, DFN-8, MSOP-8 MicroPACKAGE	Extremely high precision, excellent long-term stability, and very low 1/f noise	
OPA725	12V Op Amp	Very low noise, high speed, 12V CMOS		OPA727
OPA726	CMOS Op Amp	4V to 12V, 20MHz GBW, 30V/µs slew rate, 0.0003% (typ) at 1kHz THD+N	Outstanding ac performance, excellent CMRR, PSRR	
OPA735	Zero-Crossover Op Amp	2.7V to 12V, 0.75µA (max) I_Q/ch, 1.6MHz GBW, 115dB (min) CMRR, RRO	Zero-crossover input offers excellent CMRR over entire input range	
TLC081-083	Op Amp	IOH of 57mA at V_{DD} – 1.5V, IOL of 55 mA at 0.5 V, 16 to 19V/µs slew rate, 4.5V to 16V, 1.9mA/channel supply current, 125µA/Channel, 8.5nV√Hz input noise, 60µV input offset, ultra-small package	Very high input impedance, low-noise CMOS front end with a high-drive bipolar output stage	
TLV2375	RRIO Op Amp	Rail-to-rail input/output, 3MHz, 2.4V/µs slew rate, 2.7V to 16V supply voltage, 550µA/Channel	CMOS inputs enable use in high-impedance sensor interfaces, lower voltage operation ideal in battery-powered applications	
Data Converters				
ADS8318	High-Speed SAR	16-bit, 500kSPS, 18mW at 500kSPS power, ±1 LSB INL	Precision, excellent AC/DC performance	ADS8319
ADS8317	SAR ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL, differential input	Low power, small package, and wide supply range	ADS8326
ADS8326	Low-Power ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL	Small package, wide supply range	
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF31xx	Low-Drift Series Reference	0.2% initial accuracy, 15ppm/°C max drift, ±10mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V		REF30xx, REF33xx, REF29xx
REF32xx	Ultra-Low-Drift Series Reference	100µA, 0.2% initial accuracy, 7ppm/°C max drift, ±10mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Improves system accuracy	
REF33xx	Very-Low-Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF50xx	High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V, 10V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Processors				
MSP430F20xx	Ultra-Low-Power 16-Bit MCU	1KB/2KB Flash, 128B RAM, SPI+I^2C	8 ch. 12-bit ADC or 4 ch. 16-bit SD ADC, 4 x 4mm package	
MSP430F22x4	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 512B/1KB RAM, SPI + I^2C + UART/LIN + IrDA	12 ch. 10-bit ADC, 2 op amps	
MSP430F23x0	Ultra-Low-Power 16-bit MCU	8 to 32KB Flash, 1KB/2KB RAM, SPI + I^2C + UART/LIN + IrDA	Analog comparator, HW multiplier	
MSP430F41x	Ultra-Low-Power 16-Bit MCU	4 to 32KB Flash, 256B to 1KB RAM, SVS, 96 segment LCD	Analog comparator	
MSP430F42x	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 256B to 1KB RAM, SPI + UART, SVS, 128 segment LCD	3 x 16-bit SD ADC	
MSP430F42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC	
MSP430F43x	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 512B/1KB RAM, SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, analog comparator	
MSP430F44x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, 2x SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, HW multiplier	
MSP430F47xx	Ultra-Low-Power 16-Bit MCU	60KB Flash, 256B RAM, (4) USCI, 160 segment LCD	(4) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F241x	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, temp. sensor	8 ch. 12-bit ADC, analog comparator, HW multiplier	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Pulse Oximeter

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
MSP430F261x	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, DMA, temp. sensor	Analog comparator, 2 ch. 12-bit DAC, 8 ch. 12-bit ADC, HW multiplier	
MSP430F471xx	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, DMA, 160 segment LCD	(7) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F54xxA	Ultra-Low-Power 16-Bit MCU	128 to 256KB Flash, 16KB RAM, (4) USCI, PMM, DMA, temp. sensor	16 ch. 12-bit ADC, analog comparator, RTC, internal voltage regulator for power optimization	
MSP430FG42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC, 2 integrated op amps	
MSP430FG43x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-Bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, A-comp, 3 op amp, HW multiplier	
MSP430FG47x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 2KB RAM, SPI + I^2C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
TMS320F28x™	32-Bit MCU	32-bit architecture, fixed- or floating-point code, up to 225MIPS operation	Microcontroller integration, real-time control performance	TMS320F2823x, TMS320F2833x
TMS320F2802x/3x Piccolo™	32-Bit Microcontroller	Up to 60MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F283x Delfino™	32-Bit Floating-point Microcontroller	Up to 300MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
TMS320VC5506	DSP	200MHz, dual MAC, very low stand-by power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320V5509A, TMS320V5502
TMS320VC5509A	Low-Power DSP	Up to 200MHz, dual MAC, 256KB RAM/64KB ROM, USB 2.0 full speed, MMC/SD, 10-bit ADC	Power efficient, large on-chip memory, rich peripheral set allows for various portable connectivity; C55x code compatibility	C550x DSP
LED Drivers				
DRV777	Integrated Motor and Load Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, low output VOL 0.4V Very low input leakage (<20uA)	Easy to use and low noise with Inductive kickback protection	
ULN2003LV	Low Power 3.3V and 5V Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, switching at 8V, low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	ULN2003A, ULN2003V12, ULN2004A, ULN2803A
ULN2003V12	Low Power Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, Switching at 16V low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Pulse Oximeter

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
Toolkits				
TMDXMDKP08328	Pulse Oximeter (PO or SpO2) Analog Front End Module for the C5515 PO or SpO2 Medical Development Kit	Display of oxygen level percentage ranging from zero to 100 percent; display of pulse rate, ranging from 20 to 300; real-time display of plethysmogram on PC; sensor off detection; common signal conditioning path for red and infrared signal	Based on industry's lowest power DSP processor – TMS320C5515	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Ventilator

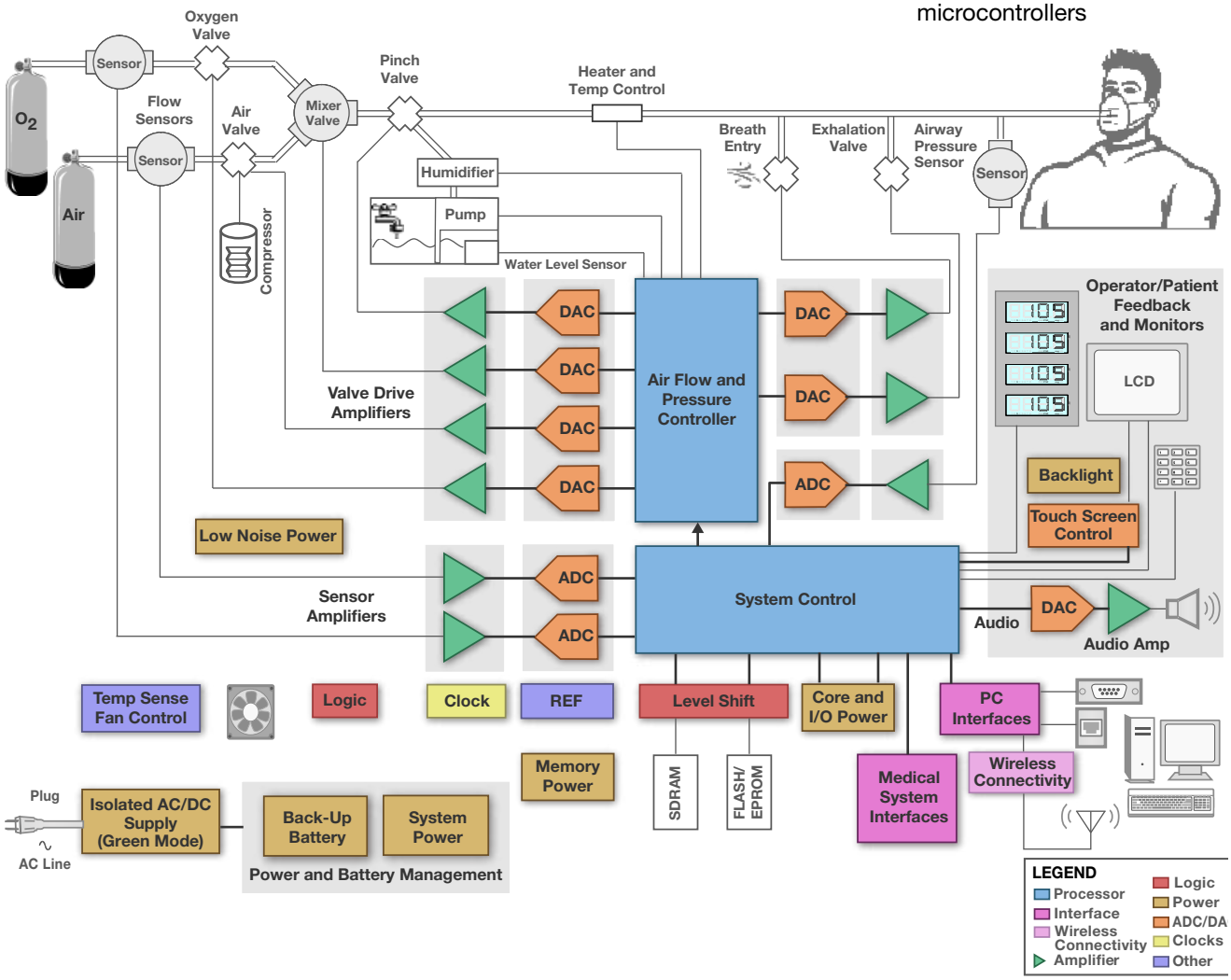
Portable Respiration Device

A portable respiration device supports a patient with the correct dose of oxygen. One pressure sensor in front of the valve measures the breathe-in air and another one after the valve measures the breathe-out pressure. A microprocessor uses the data from the two pressure sensors and single flow sensor to calculate the output of the valve that is regulating the airflow. The medical staff can set the right air flow by a touch screen or key pad. A portable device, used in an ambulance for example, has sophisticated power management circuitry to support mains and battery operation.

TMS320C2000™ 32-bit controllers are used in portable respiration applications like portable oxygen concentrators because the real-time control capability allows for very precise control of the BLDC motor, even at high speeds. This optimizes system power consumption and enhances the durability and reliability necessary in portable respiratory equipment.

Other TI Components to Consider

- F2802x/F2803x Piccolo™ series 32-bit MCUs
- DRV103 as valve driver
- Power amplifier family OPA54x, OPA56x as valve driver
- bq power management ICs for battery charging and fuel gauge
- LED drivers
- Low-power wireless for future designs
- RS-485 (SN65HVD3082), CAN (SN65HVD251) or other interface ICs for the communication between the sensor and controller board
- Tiva™ C Series ARM® Cortex-M4 microcontrollers



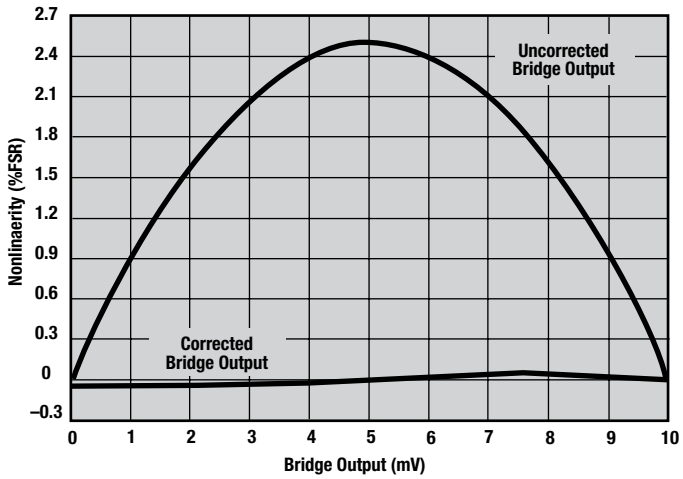
Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Portable respiratory device system block diagram.

Ventilator

Pressure sensors convert a physical value (weight, level, force, and flow) into a differential signal in the mV/V range and are referred to as metal thick-film, ceramic or piezo-resistive. The majority of designers use the cost-effective piezo-sensors (25mbar to 25bar). However, these are very nonlinear, temperature dependent and have large offset and offset drift. Plus, they require attention to electronic calibration and compensation.

The block diagram (below) shows the functional block diagram of a pressure signal conditioning system.



PGA309 bridge pressure nonlinearity correction.

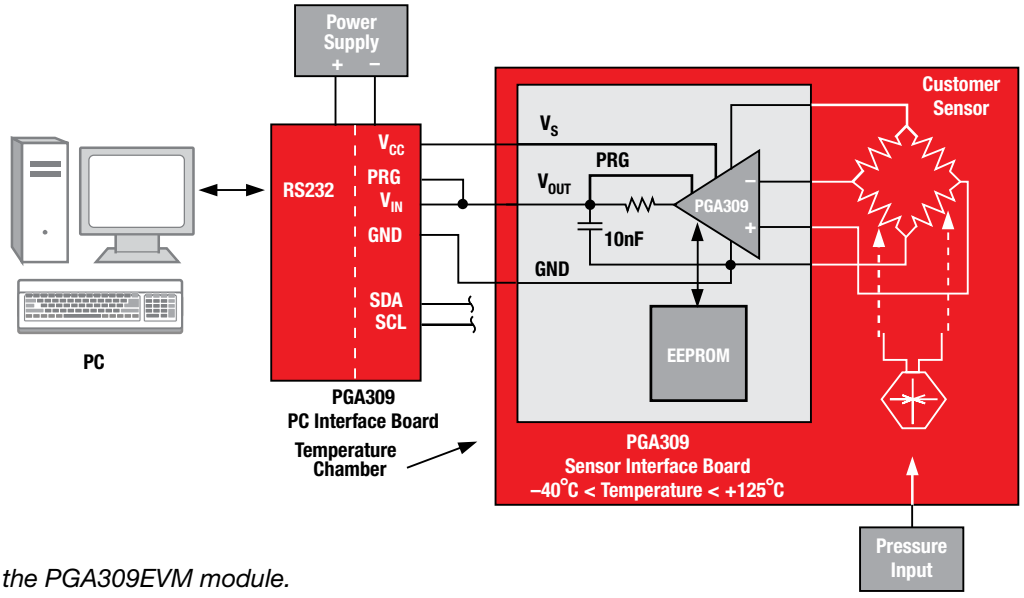
Sensor Signal Conditioning — performs all necessary functions to calibrate, compensate for temperature variance, scale, and linearize the sensor signal.

Analog/Digital Processing — there are two ways to convert and linearize the sensor signal. The analog technique results in an analog solution and provides an analog output. This technique is inexpensive and fast, but limited to a maximum of 11- to 16-bit resolution. Digital is more precise, up to 24-bits, and provides a digital output at moderate speed.

The bridge excitation linearization circuit is optimized for bridge pressure nonlinearities with a parabolic shape (shown above). The linearization circuit is digitally programmable, but the pure analog signal conditioning side is handled by the same process as in TI's well-known 4-20mA transmitters, such as XTR105, XTR108 or XTR117. The heart of the PGA309 is a precision, low-drift programmable gain instrumentation amplifier using an auto-zero technique and includes a programmable fault monitor and over/underscale limiter. It also offers a digital temperature compensation circuit. Calibration is carried out either via a one-wire digital serial interface or through a two-wire industry-standard connection.

Calibration parameters are stored in an external nonvolatile memory to eliminate manual trimming and achieve long-term stability. An evaluation module, PGA309EVM (see below) includes software and calibration sheet for easy evaluation of your sensor + PGA309 combination.

The highly integrated, CMOS PGA309, available in TSSOP-16, is tailored for bridge pressure sensors and adds to TI's portfolio of highly flexible, lowest noise amplifier and instrumentation amplifier solutions that also include the OPAx227, OPAx132, OPA335, OPA735, INA326, INA333, INA118 and INA122.



Block diagram of the PGA309EVM module.

Ventilator

32-Bit Microcontrollers

TMS320C28x™

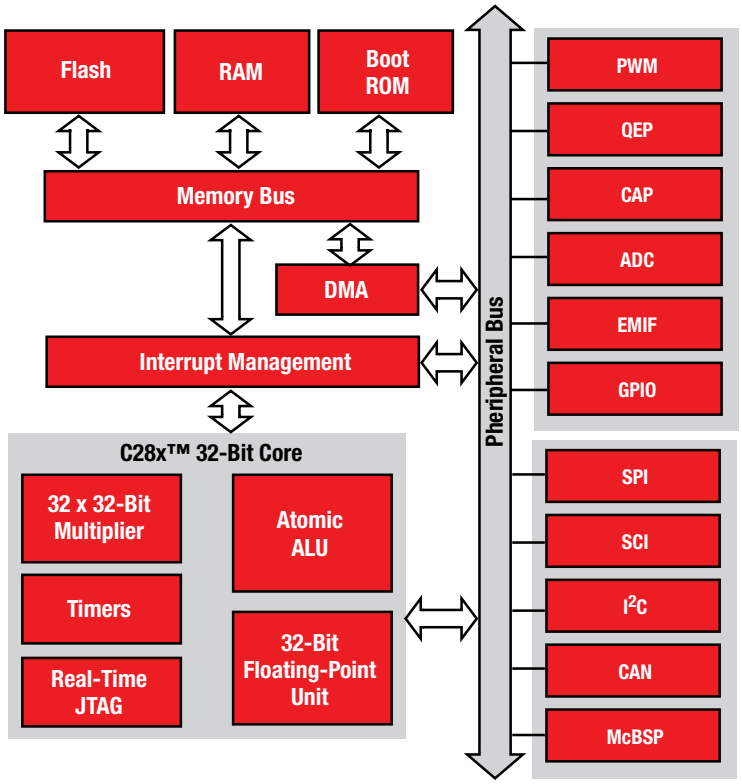
Get samples and datasheets at: **www.ti.com/c2000**

Key Features

- Floating-point and fixed-point microcontrollers
- Up to 150MIPS or 300MFLOPS
- A mix of 16-bit and 32-bit instructions
- Unified memory architecture
- Best-in-class compiler efficiency
- Single-cycle 32 x 32-bit multiply accumulate
- Up to 512KB on-chip Flash and 68KB on-chip SRAM
- 12-bit ADC with 80ns conversion time and 16 input channels
- Six-channel DMA
- High-resolution PWM with 150ps accuracy
- PWM microcontrollers with programmable deadband-, phase- or duty-cycle control and up to six trip zones can create any waveform required
- SCI, SPI, I^2C, McBSP and CAN ports
- Industrial (–40°C to 85°C) or extended (–40°C to 125°C) temperature ranges. Fully automotive qualified.

The C2000™ MCU uses a modified Harvard architecture to unify a high-performance 32-bit core with different on-chip peripherals. An advanced interrupt management system ensures fast interrupt response. Combined with integrated Flash and RAM memory blocks, the C2000 MCU provides a powerful single-chip solution ideal for many embedded applications.

The C28x™ generation of microcontrollers is optimized for delivering the highest-performance control solution with the best time to market.



TMS320C28x™ 32-bit microcontroller block diagram.

Ventilator

Complete Voltage-Output, Programmable Bridge Sensor Signal Conditioner
PGA309

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/pga309**

Key Features

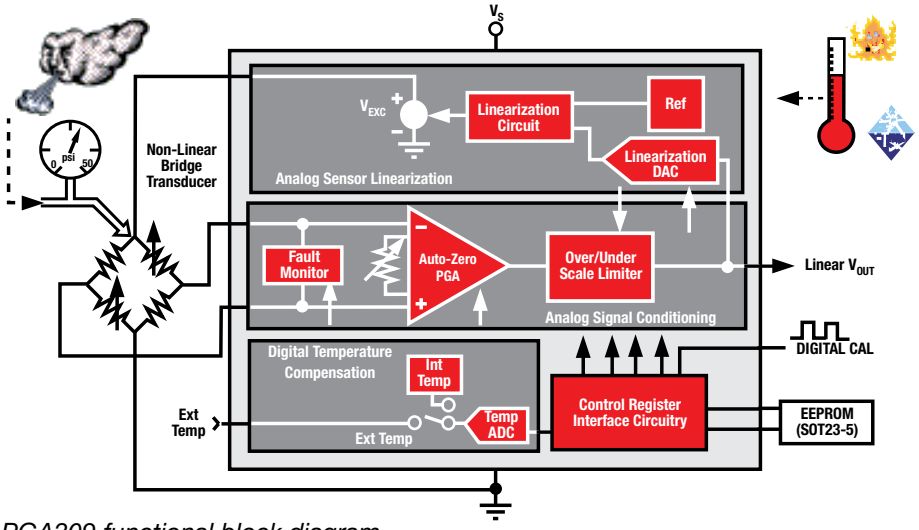
- Ratiometric or absolute voltage output
- Digitally calibrated via single-wire or two-wire interface
- Eliminates potentiometer and trimming
- Low, time-stable total adjusted error
- +2.7V to +5.5V operation
- Packaging: Small TSSOP-16

Applications

- Bridge sensors
- Remote 4mA to 20mA transmitters
- Strain, load, weight scales
- Automotive sensors

*See also the new PGA308

The PGA309 is a programmable analog signal conditioner designed for bridge sensors. The analog signal path amplifies the sensor signal and provides digital calibration for zero, span, zero drift, span drift, and sensor linearization errors with applied stress (pressure, strain, etc.). The calibration is done via a one-wire digital serial interface or through a two-wire industry-standard connection. The calibration parameters are stored in external nonvolatile memory (typically SOT23-5) to eliminate manual trimming and achieve long-term stability.



PGA309 functional block diagram.

High-Voltage, High-Current Operational Amplifier
OPA549

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/opa549**

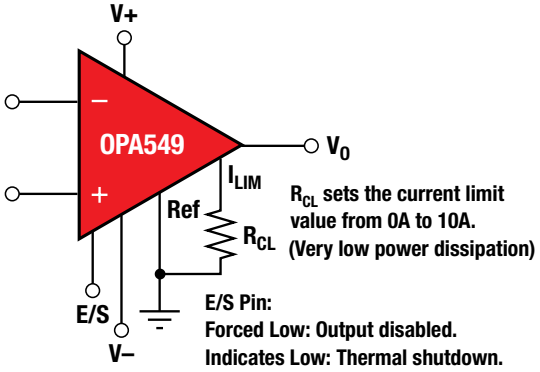
Key Features

- High output current: 8A continuous, 10A peak
- Wide power supply range:
  - Single supply: +8V to +60V
  - Dual supply: ±4V to ±30V
- Wide output voltage swing
- High slew rate: 9V/µs
- Control reference pin
- Fully protected: thermal shutdown, adjustable current limit
- Output disable control
- Packaging: 11-pin power package

The OPA549 is a high-voltage, high current op amp designed for driving a wide variety of loads. It provides low-level signal accuracy and high output voltage and current. It is internally protected against overtemperature conditions and current overloads. In addition, the OPA549 provides an accurate, user-selected current limit. Unlike other designs which use a "power" resistor in series with the output current path, the OPA549 senses the load indirectly. This allows the current limit to be adjusted from 0A to 10A with a resistor/potentiometer, or controlled digitally with a voltage-out or current-out DAC.

Applications

- Valve, actuator drivers
- Synchro, servo drivers
- Test equipment
- Transducer excitation
- Power supplies



OPA549 functional block diagram.

Ventilator

High-Side Measurement, Bidirectional, Zerø-Drift Current-Shunt Monitor

INA210, INA211, INA212, INA213, INA214

Get samples and datasheets at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **ina210**, **ina211**, **ina212**, **ina213** or **ina214**)

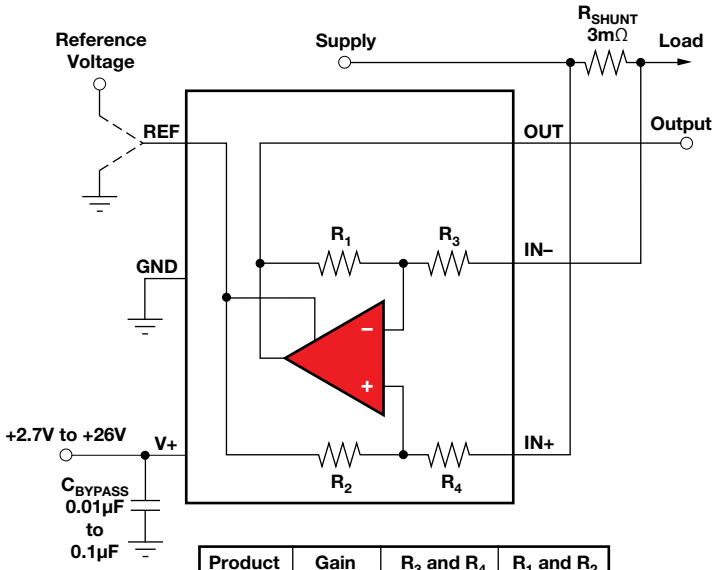
Key Features

- Wide common-mode range: –0.3 to 26V
- Offset voltage: ±35µV (max) (enables shunt drops of 10mV full-scale)
- Accurate:
  - Gain: ±1% (max)
  - Offset drift: 0.05µV/°C (max)
  - Gain drift: 25ppm/°C (max)
- Choice of gain range: 50 to 1000V/V
- Supply voltage: +2.7 to +18V
- Quiescent current: 100µA (max)
- Packaging: SC70

Applications

- Medical equipment
- Notebook computers
- Cell phones
- Battery chargers

The INA21x devices are voltage-output-current shunt monitors that can sense drops across shunts at common-mode voltages from –0.3 to 26V, independent of the supply voltage. Five gains are available: 50V/V, 100V/V, 200V/V, 500V/V or 1000V/V. The low offset of the zero-drift series architecture enables current sensing with maximum drops across the shunt as low as 10mV full-scale.



Product	Gain	R_3 and R_4	R_1 and R_2
INA210	200	5kΩ	1MΩ
INA211	500	2kΩ	1MΩ
INA212	1000	1kΩ	1MΩ
INA213	50	20kΩ	1MΩ
INA214	100	10kΩ	1MΩ

Typical device configuration options.

Ventilator

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA210/11/12/13/14	Current Shunt Monitor	±35µV (max) offset, 0.05µV/°C (max) drift, 2.7 to 18V supply voltage	Enables current sensing with maximum drops across the shunt as low as 10mV full-scale	
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA549	Power Amplifier	8A continuous, 10A peak output current, 9µs slew rate	Wide supply range, thermal protection	OPA547, OPA548
OPA564	Power Amplifer	1.5A, 24V, 17MHz, power operational amplifier	Near rail output, current and thermal protection	
OPA567	Power Amplifier	2A output, 150mV of rails with I/O = 2A output swing	Thermal protection, adj. current limit	OPA569
PGA309	Prog. Sensor Conditioner	Sensor error compensation: span, offset, temp drifts	Complete bridge sensor conditioner	PGA308
THS452X	Low Power FDA	1.14mA quiescent current (typ), +2.5V to 5.5V supply, 4.6nV/√Hz voltage noise	Low power enables high accuracy, low crosstalk in multichannel options	THS4522, THS54524
Data Converters				
ADS1258	Delta-Sigma ADC	16-channel, 24-bit, 125kSPS, 23.7kSPS/channel	Fastest multi-channel, delta-sigma ADC, measures all 16 inputs in <675µs	ADS1251, ADS1253,
ADS1271	Delta-Sigma ADC	24-bit, 105kSPS, serial interface, SPI w/FSYNC	Designed for multi-channel systems	ADS1274, ADS1278, ADS1284
ADS1278	Delta-Sigma ADC	24-bit, 128kSPS, 8 channels, 111dB SNR	Simultaneous measurement, onboard decimation filter	ADS1271, ADS1274
ADS1298	ECG/EEG AFE	24-bit, 8 PGA, 8 ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1294, ADS1296, ADS1198, ADS1251/58
ADS8318/19	High-Speed SAR	16-bit, 500kSPS, 18mW at 500kSPS power, ±1 LSB INL	Precision, excellent AC/DC performance	
ADS8326	Low-Power ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL	Small package, wide supply range	
DAC7564	Quad DAC	Ultra-low glitch, voltage output DAC	Internal low drift reference	DAC8564
DAC7568	Octal DAC	Ultra-low glitch, voltage output DAC	Internal low drift reference	
DAC8411	High Resolution DAC	16-bit, low power DAC	Small size, wide supply range	DAC8311, DAC7311
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics acelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
MSP430F20xx	Ultra-Low-Power 16-Bit MCU	1KB/2KB Flash, 128B RAM, SPI+I²C	8 ch. 12-bit ADC or 4 ch. 16-bit SD ADC, 4 x 4mm package	
MSP430F22x4	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 512B/1KB RAM, SPI + I²C + UART/LIN + IrDA	12 ch. 10-bit ADC, 2 op amps	
MSP430F23x0	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 1KB/2KB RAM, SPI + I²C + UART/LIN + IrDA	Analog comparator, HW multiplier	
MSP430F41x	Ultra-Low-Power 16-Bit MCU	4 to 32KB Flash, 256B to 1KB RAM, SVS, 96 segment LCD	Analog comparator	
MSP430F43x	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 512B/1KB RAM, SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, analog comparator	
MSP430F44x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, 2x SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, HW multiplier	
MSP430F471xx	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, DMA, 160 segment LCD	(7) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F54xxA	Ultra-Low-Power 16-Bit MCU	128 to 256KB Flash, 16KB RAM, (4) USCI, PMM, DMA, temp. sensor	16 ch. 12-bit ADC, analog comparator, RTC, internal voltage regulator for power optimization	
MSP430FG42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC, 2 integrated op amps	
MSP430FG43x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-Bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I²C + UART/LIN + IrDA, 160 LCD	12 ch. 12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amps, HW multiplier	
MSP430FG47x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 2KB RAM, SPI + I²C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, A-comp, 2 op amps	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Ventilator

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	
TMS320C28x™	32-Bit MCU	Up to 512KB on-chip flash and 68KB on-chip SRAM, up to 150MIPS or 300MFLOPS	Optimized for delivering the highest-performance control solution with the best time to market	
TMS320C5000™	DSP	Power efficient, high performance	Fixed-point DSP with industry's best combination of standby and dynamic power consumption	
TMS320F28x™	32-Bit MCU	32-bit architecture, fixed- or floating-point code, up to 225MIPS operation	32-bit microcontroller integration, real-time control performance	TMS320F2823x, TMS320F2833x
TMS320F2802x/3x Piccolo	32-Bit Microcontroller	Up to 60 MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F2808	32-Bit MCUs	100MIPS, 8KB ROM, 36KB RAM, 128KB Flash, 12-bit ADC	I^2C, 4 SPI, 2 SCI, 2 CAN	
TMS320F283x Delfino	32-Bit Floating-point Microcontroller	Up to 300 MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
TMS320F28234	32-Bit MCUs	150MIPS, 8KB ROM, 68KB RAM, 256KB Flash, 12-bit ADC	McBSP, 1 SPI, 2 SCI, 2 CAN	
TMS320F28015	32-Bit MCUs	60MIPS, 8KB ROM, 12KB RAM, 32KB Flash, 12-bit ADC	I^2C, 1 SPI, 1 SCI	
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
TMS320VC5506	DSP	200MHz, dual MAC, very low standby power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320V5509A, TMS320V5502
Interface				
SN65HVD1050	CAN Transceiver	–27V to 40V bus-fault protection, meets or exceeds ISO11898-2	High EMI, low EME	HVD234 is 3.3V version
SN65HVD3082	RS-485 Transceiver	1/8 unit load — up to 256 nodes on a bus, 15kV ESD protection	Glitch-free power-up/down bus inputs and outputs	
LED Drivers				
DRV777	Integrated Motor and Load Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, low output VOL 0.4V Very low input leakage (<20uA)	Easy to use and low noise with Inductive kickback protection	
ULN2003LV	Low Power 3.3V and 5V Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, switching at 8V, low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	ULN2003A, ULN2003V12, ULN2004A, ULN2803A
ULN2003V12	Low Power Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, Switching at 16V low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	

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Continuous Positive Airway Pressure (CPAP)

Continuous positive airway pressure (*CPAP*) is a method of respiratory ventilation used mainly for the treatment of sleep apnea at home. Sleep apnea occurs during sleep when the muscles tend to relax naturally, causing the upper airway to narrow. This narrowing reduces the amount of oxygen in the blood and causes arousal from sleep.

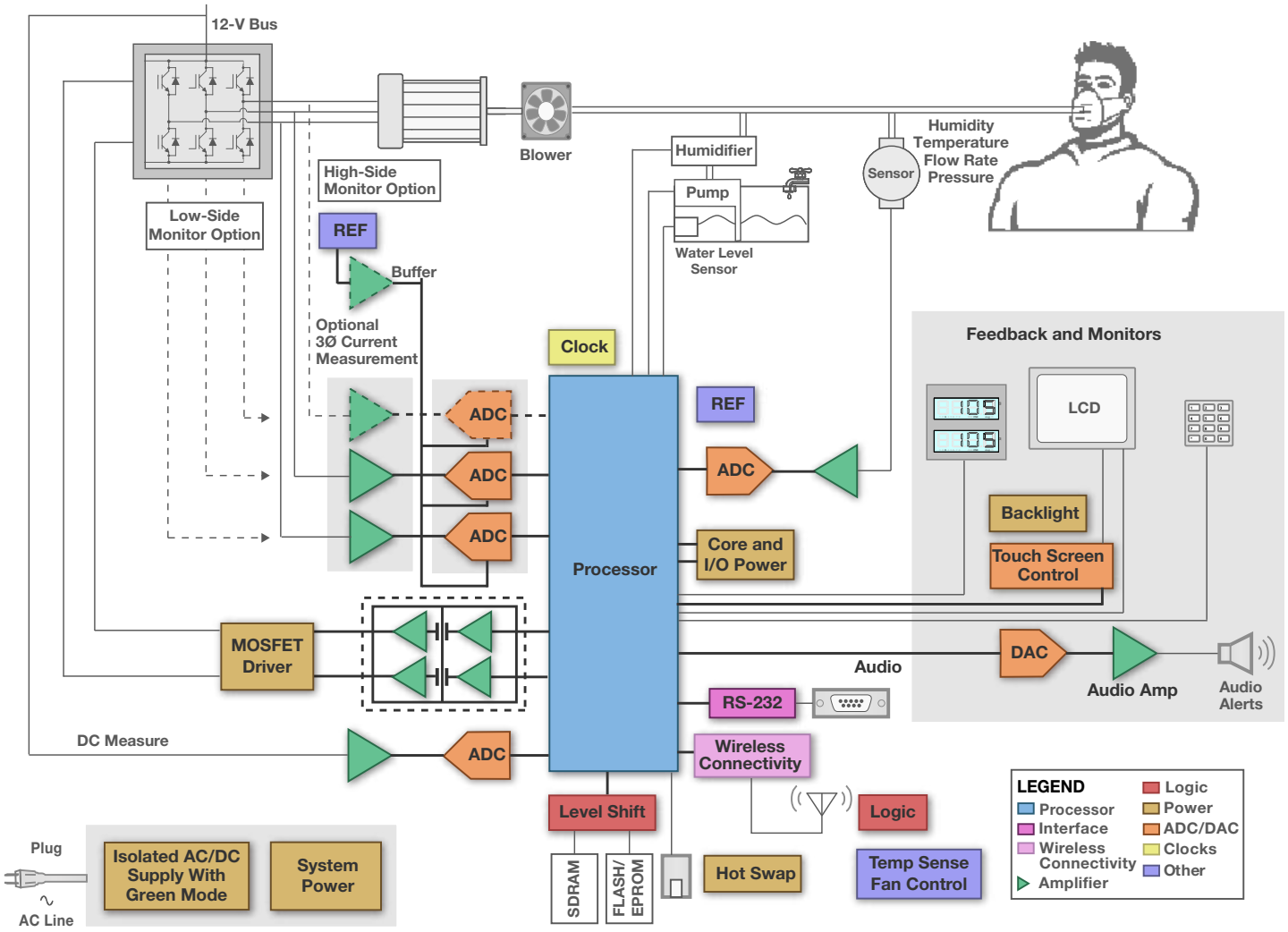
Pressure sensors play an important role in respiration equipment. In addition to converting physical values such as airway pressure and flow into a differential signal, air and flow sensors generate signals that help the microprocessor regulate the motor to adjust/maintain the desired pressure as the person inhales or exhales.

The sensors are very cost-effective. Large offset and offset drift cause the signals to be off-scale, temperature-variant and nonlinear. Amplifiers with low offset voltage and drift over time and temperature are ideal for signal conditioning.

DC motor control can be accomplished by monitoring at least two of the three current phases, along with the DC bus voltage feeding the motor drive bridge. For phase currents, two approaches can be used: high-side or low-side.

Direct phase measurement, or high-side, requires high-speed difference amplifiers or current-shunt monitors and is generally more accurate. The low-side approach takes measurements near the half-bridge ground connection and uses simpler amplifiers that can be less costly but also less precise. The DC motor is driven by discrete FETs.

Devices in TI's DRV family offer an integrated driver and bridge with



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

CPAP system block diagram.

Continuous Positive Airway Pressure (CPAP)

thermal protection and are smaller, more precise and much more efficient.

The microprocessor performs multiple operations. These operations include sampling the pressure signals and computing a desired airway pressure and flow level to communicate with the motor. To achieve these operations efficiently and in real-time, a high-speed, low-power, highly-integrated microprocessor should be used. A high-quality DSP can be used for such applications and will also provide the patient ultra-quiet operation.

High-Performance 32-Bit Microcontroller for CPAP Machines

TMS320C2000™

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/c2000**

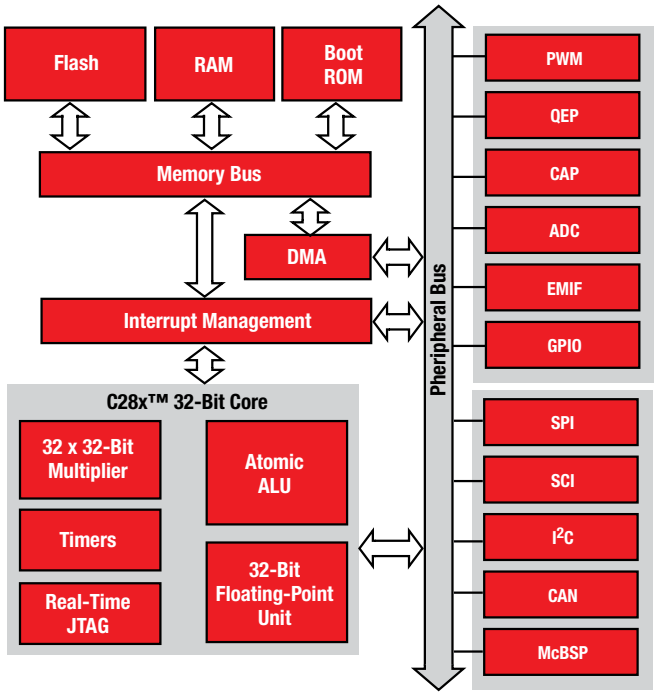
Continuous Positive Airway Pressure (CPAP) machines are an effective means of preventing intubation, decreasing mortality in patients with acute respiratory failure, helping patients with sleep apnea and reducing chronic respiratory failure.

Designers of CPAP machines are concerned with the efficiency of the motor that drives the continuous airflow to the patient, and try to reduce the number of components on the system board for lower cost, easier development and quicker time to market. CPAP systems designers value the TMS320C2000 for its exceptional capabilities, including:

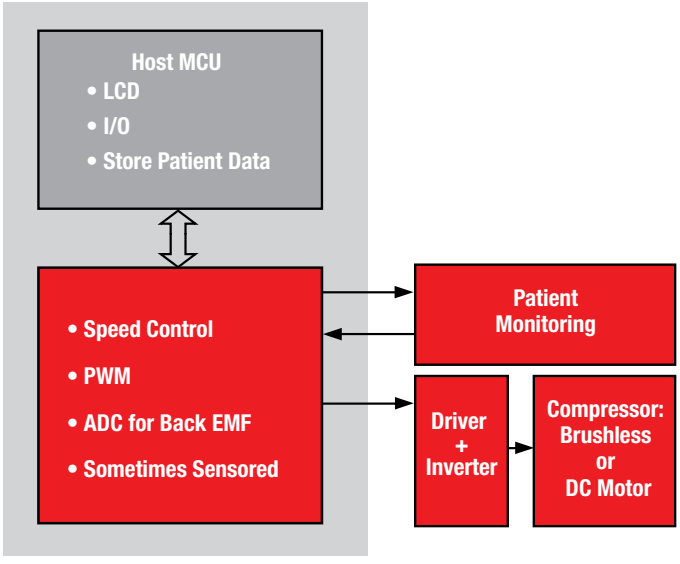
1. TMS320C2000 32-bit microcontrollers are high-performance, low-cost ICs that control motor speed, position and torque in real time. If necessary these controllers can even provide the processing power for executing highly sophisticated position and speed estimation algorithms to control the motor using data from resolver, encoder and hall-effect sensor.
2. These high-performance controllers not only provide accurate control of the motor but can also provide additional MIPS and peripheral integration to act as the host MCU. These ICs can perform up to 150MIPS and have a high level of peripheral integration with on-chip flash, a 12-bit, 16-channel ADC with up to 12.5MSPS performance and multiple GPIO pins so designers can use a single controller for a lower cost.
3. The C2000™ platform has a free extensive motor control library (*www.ti.com/c2000appsw*) that can help a developer get the software framework necessary to control either a single-phase or three-phase BLDC motor. In addition, the C-compiler efficiency eliminates the need for most assembly coding.

Key Features

- Real-time control reducing overall system cost
- Scalable controller offers from sub-$2 for 150MIPS
- Software and tool compatibility across full family



TMS320C2000™ 32-bit MCU block diagram.



TMS320C2000™ 32-bit MCU in simplified patient monitoring system.

Continuous Positive Airway Pressure (CPAP)

Key Features (Continued)

- On-chip programmable flash
- C-compiler efficiency eliminates the need for most assembly coding
- 10- or 12-bit ADCs with up to 16 channels and 12.5MSPS
- Independent or complementary PWM with deadband
- Independent duty-cycle or phase control
- 150ps high-resolution PWM
- Encoder interfaces and event capture inputs
- CAN 2.0B, SCI, SPI, and I^2C port interfaces
- Long product life cycle assures supply continuity

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
ISO7231C	Triple-Channel, 2/1, 25Mbps Digital Isolator	Silicon-integrated SiO_2 dielectric capacitor; 0 to 150Mbps and DC signal pass with fail-safe; 1ns skew, 1ns jitter, 1ns pulse distortion; input threshold; noise filter; high magnetic immunity (1E6 > inductive)	Proven reliability of SiO_2 dielectric, stable over temperature and moisture; lowest skew, jitter and pulse width distortion; filters noisy signals before entering system; high immunity for noisy environments	
ISO7241M	Quad-Channel, 3/1, 150Mbps Digital Isolator	Silicon-integrated SiO_2 dielectric capacitor; 0 to 150Mbps and DC signal pass with fail-safe; 1ns skew, 1ns jitter, 1ns pulse distortion; input threshold; noise filter; high magnetic immunity (1E6 > inductive)	Proven reliability of SiO_2 dielectric, stable over temperature and moisture; lowest skew, jitter and pulse width distortion; filters noisy signals before entering system; high immunity for noisy environments	
OPA4376	Precision Op Amp	Quad, 5.5MHz GBW, 2V/µs slew rate, 0.95mA/ch I_Q, 76dB CMRR, 7.5nV/√Hz noise	Precision, low power	OPA4727, OPA2376
INA169	Current-Shunt Monitor	2.7V to 60V, 60µA (typ) I_Q, unipolar, high-side current measurement	High speed, small size	INA168, INA139
INA170	Current-Shunt Monitor	2.7V to 40V supply, 2.7V to 60V common-mode voltage, 75µA (typ) I_Q, bidirectional	Low power, current output	INA193, INA138
INA210	Current-Shunt Monitor	–0.3V to 26V common-mode range, ±35µV offset, 100µA I_Q, 0.5µV/°C (max) offset drift	Voltage output, bidirectional, zero-drift series	INA138, INA193
INA332	Instrumentation Amp	0.07%, 2ppm/°C, G = 5 gain accuracy, 73dB CMRR, 0.5pA IB, 490µA (max/ch) I_Q	Single or bipolar operation, low noise	INA326, INA338
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50 µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA118
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05 µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA2365	Precision Op Amp	Dual, zero crossover, 0.0006% THD+N, 100dB CMRR, RRIO, 4.5nV/√Hz noise, 50MHz GBW, 200µV input offset	Superior performance, excellent for driving single-supply ADCs	OPA2333
OPA376	Precision Op Amp	7.5nV/√Hz noise, 760µA(typ)/ch Iq, 5µV (typ) offset, input EMI filter, RRO	Low noise, low power, low input bias	OPA340, OPA337
TLC2264	Op Amp	Quad, 12nV/√Hz (typ) noise, 1pA bias current, 500µA (max) I_Q, RRO	Single or split supply, low noise	TLC2274
THS452X	Low power FDA	+2.5V to 5.5V supply, 1.14mA (typ) quiescent current, 4.6nV/√Hz voltage noise	Low power, low noise enables high accuracy	THS4522, THS4524
TPA2006D1	Analog-Input Class-D Amp	1.45W mono, filter-free Class D, 1.8V shutdown		
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA2016D2	Analog-Input Class-D Amp	1.7W stereo, Class D with dynamic range compression and automatic gain control		
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	

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Continuous Positive Airway Pressure (CPAP)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters				
ADS1258	Delta-Sigma ADC	16-channel, 24-bit, 125kSPS, 23.7kSPS/channel	Fastest multi-channel, delta-sigma ADC, measures all 16 inputs in <675µs	ADS1158, ADS1248
ADS7952	SAR ADC	12-bit, 1MSPS, 70dB SNR, 11.5mW power	Zero latency, ideal for multi-channel systems	ADS7951, ADS7953
ADS8317	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Excellent linearity, micropower, high speed	ADS8422
ADS8318	SAR ADC	16-bit, 500kSPS, 18mW (typ) power, 95.5dB SNR, ±1 LSB (max) INL	Zero latency, serial interface, low power	ADS8519, ADS8321
ADS8326	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Low noise, low power, high speed	ADS8325
ADS8331/32	SAR ADC	16-bit, 500kSPS, 4/8 channels, with serial interface	Mux out feature can be used to reduce system part count and overall cost	ADS8342
ADS8201	Low-Power SAR ADC	8 channel, 12-bit, 100kSPS, 1.32mW power consumption at 100kSPS	Full on-chip data acquisition system	ADS7870
ADS8472	SAR ADC	16-bit, 1MSPS, ±0.4LSB (typ) INL	Zero latency, low power	
TLV320DAC3120	Low-Power Audio DAC	Mono DAC with 2.5W mono Class-D speaker amplifier; miniDSP for audio processing	Longer battery life, better audio quality, lower cost	TLV320DAC3101
TLV320DAC32	Audio DAC	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		
TSC2000	Touch-Screen Controller	4-wire programmable touch-screen controller with 8-/10-/12-bit 125kHz ADC and SPI interface		
TSC2003	Touch-Screen Controller	4-wire touch-screen controller		
TSC2006	Touch-Screen Controller	Nano-power touch-screen controller with SPI serial interface		
TSC2007	Touch-Screen Controller	Nano-power touch-screen controller with I^2C serial interface		
TSC2046	Touch-Screen Controller	4-wire touch-screen controller with low-voltage digital I/O		
TSC2200	Touch-Screen Controller	Programmable 4-wire touch-screen controller with 12-bit 125kHz ADC and keypad interface		
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF3030	Series Voltage	3.0V, 50ppm/°C, 50µA in SOT23-3	Low power, small size	REF2930
REF3130	Series Voltage	20ppm/°C max, 100µA, SOT23-3	Precision, low power, small size	REF3330
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Interface				
ISO721	Single-Channel, 100Mbps Digital Isolator	Silicon-integrated SiO_2 dielectric capacitor; 0 to 150Mbps and DC signal pass with fail-safe; 1ns skew, 1ns jitter, 1ns pulse distortion; input threshold; noise filter; high magnetic immunity (1E6 > inductive)	Proven reliability of SiO_2 dielectric, stable over temperature and moisture; lowest skew, jitter and pulse width distortion; filters noisy signals before entering system; high immunity for noisy environments	
ISO7221C	Dual-Channel, 1/1, 25Mbps Digital Isolator	Silicon-integrated SiO_2 dielectric capacitor; 0 to 150Mbps and DC signal pass with fail-safe; 1ns skew, 1ns jitter, 1ns pulse distortion; input threshold; noise filter; high magnetic immunity (1E6 > inductive)	Proven reliability of SiO_2 dielectric, stable over temperature and moisture; lowest skew, jitter and pulse width distortion; filters noisy signals before entering system; high immunity for noisy environments	
Clocking				
CDCE913	Programmable 1-PLL VCXO Clock Synthesizer with 2.5 or 3.3V LVCMOS Outputs	Input clock: X-tal (8 to 32MHz) or LVCMOS up to 150MHz; VCXO input with ±150ppm (typ) pulling range; output frequencies up to 230MHz; three low-jitter, low-skew, high-performance LVCMOS output fan-out buffers	Wide input/output frequency range supports wide frequency ratio for audio/video clocking; easy frequency synchronization; fractional PLL enables zero PPM clocking generation; integrated fan-out buffers reduce clock distribution cost	
CDCEL913	Programmable 1-PLL VCXO Clock Synthesizer with 1.8V LVCMOS Outputs	Input clock: X-tal (8 to 32MHz) or LVCMOS up to 150MHz; VCXO input with ±150ppm (typ) pulling range; output frequencies up to 230MHz; three low-jitter, low-skew, high-performance LVCMOS output fan-out buffers	Wide input/output frequency range supports wide frequency ratio for audio/video clocking; easy frequency synchronization; fractional PLL enables zero PPM clocking generation; integrated fan-out buffers reduce clock distribution cost	

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Continuous Positive Airway Pressure (CPAP)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
TMS320C2000™	High-Performance Microcontroller	32-bit, up to 150MIPS, up to 12.5MSPS	High-performance, low cost	
TMS320F2802x/3x Piccolo™	32-Bit Microcontroller	Up to 60MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F28015	High-Speed Microcontroller	32-bit digital signal controller with flash		
TMS320F2812	High-Speed Microcontroller	32-bit digital signal controller with flash		
TMS320F28232	Digital Signal Controller	High-performance static CMOS technology. Highly integrated, high-performance solutions for demanding control applications		
TMS320F28234	Digital Signal Controller	High-performance static CMOS technology. Highly integrated, high-performance solutions for demanding control applications		
TMS320F28235	Digital Signal Controller	High-performance static CMOS technology. Highly integrated, high-performance solutions for demanding control applications		
TMS320F283x Delfino	32-Bit Floating-point Microcontroller	Up to 300 MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
TMS320F28335	Digital Signal Controller	High-performance static CMOS technology. Highly integrated, high-performance solutions for demanding control applications		
TMS320VC5509A	Low-Power DSP	Up to 200MHz, dual MAC, 256KB RAM/64KB ROM, USB 2.0 full speed, MMC/SD, 10-bit ADC	Power efficient; large on-chip memory, rich peripheral set allows for various portable connectivity; C55x™ code compatibility	C550x DSP
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB Flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	

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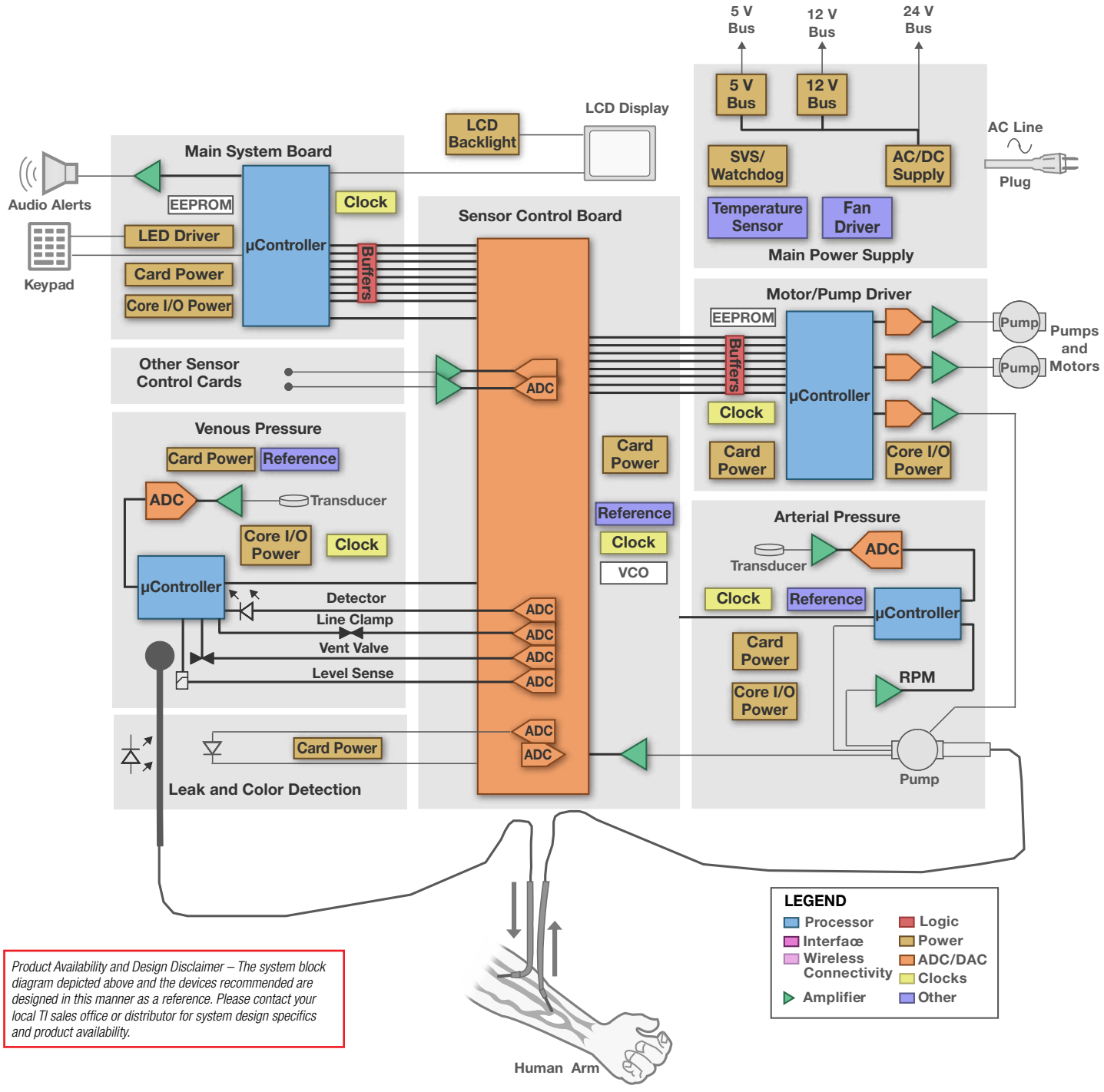
Dialysis Machine

A dialysis machine is an artificial kidney that treats the blood of people who have inadequate kidney function. Dialysis machines are processor-based and incorporate electromechanically controlled extracorporeal blood paths that leverage pumps and semi-permeable dialyzer membranes to filter the person's blood.

Satisfying Safety Criteria

From an operational perspective, dialysis equipment must meet specific safety criteria. One of these criteria is single-fault tolerance, which means no single point-of-failure in the pumps, motors, tubes or electronics will endanger the patient. To achieve single-point tolerance, there must be several redundant components and circuits, as well as "watchdog" managed-disengage system mechanisms.

A safe mode of operation involves disabling the arterial blood pump and clamping the venous line to prevent



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Dialysis machine system block diagram.

Dialysis Machine

unsafe blood from flowing to the patient. Both active and passive components, such as control devices, sensors, motors, heaters, pumps and valve drivers, are needed for this type of functionality.

The typical electronic circuits in a dialysis machine include the sensor control board, arterial and venous control card, and motor and pump drivers.

Sensor Control Board

Sensor control boards contain analog-to-digital converters (ADCs), precision references, clocks and VCOs, as well as instrumentation or operation amplifiers. Although these circuits need to respond quickly, they are often geared more toward precision than high speed to satisfy the need to verify a measurement or alarm signal and coordinate the response across the entire system instead of reacting to random stimuli. The ADCs used must provide high reliability, good noise immunity (since there are motors and pumps in the system) and good precision.

Arterial and Venous Control Card

These portions of a system may include functions like arterial and venous pressure sensors, blood pumps, line clamps, level sensors, blood detection sensors and various monitoring and control features.

TI's C2000™ 32-bit microcontrollers are a great fit for motor-control and industrial-sensor applications. These MCUs provide drive and diagnostic capabilities, while allowing the implementation of RPM and motor coil current sensing. They also offer the ability to read pressure transducers and can support required system redundancy at a minimal cost.

Motor and Pump Drivers

There are a number of motors, pumps, valves and heaters in a dialysis machine. Each of these may need a specific drive circuit, while some can be driven directly by a C2xxx controller. Selecting the appropriate digital-to-analog converter (DAC) and drive amplifier is important to motor/pump control and life expectancy. Driving any of the values or motors too hard, with signals that are to noisy, can cause them to run hot and degrade quickly. This can negatively affect the patient's comfort while connected to the machine.

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA118	Instrumentation Amp	110dB CMRR, 5nA (max) bias current, 50µV (max) offset	Wide BW at high gains, ±1.35V to ±18V supply	INA128
INA126	Instrumentation Amp	175µA/ch supply, 3µV/°C (max) drift, 250µV (max) offset	Precision low power, ±1.35V to ±8V supply	INA2126 (dual)
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA326
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA141	Precision Op Amp	10MHz, 6.5nV/$\sqrt{Hz}$, ±4.5V to ±18V, 1.8mA typical, FET input: I_B = 20pA max	Common mode voltage range includes GND	OPA827
OPA211	Precision Op Amp	1.1nV/$\sqrt{Hz}$ noise at 1kHz, ±2.25V to ±18V supply, 80MHz BW	Unity gain stable, RRO, wide supply range	OPA227
OPA2822	High-Speed Amp	Dual, 2nV/$\sqrt{Hz}$ input noise, 1.2mV input offset, 240MHz GBWP, 90mA output, 4.8mA/ch I_Q, +5V to +12V supply	High speed, wide input and output voltage swing, excellent DC accuracy	OPA2690, OPA842
OPA333	Precision Op Amp	1.8V (min) V_S, 0.017mA (max)/ch I_Q, V_{os} 10µA (max), V_{os} drift 0.05 µV/°C (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA365	Op Amp	Zero crossover, 0.0006% THD+N, 100dB CMRR, RRIO, 4.5nV/$\sqrt{Hz}$ noise, 50MHz GBW, 200µV input offset	Superior performance, excellent for driving single-supply ADCs	OPA333, OPA211
OPA695	High-Speed Amp	1400MHz BW (G = +2), 4300V/µs slew rate, 129mW power, ±4.2V output voltage swing	Wide bandwidth, current feedback, low power, excellent accuracy	OPA847, OPA691
THS4521	Low Power FDA	1.14mA (typ) quiescent current, fully differential rail-to-rail output, negative rail input	Low power, fully differential	THS54522, THS54524
TPA2006D1	Analog-Input Class-D Amp	1.45W mono, filter-free Class D, 1.8V shutdown		
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA751
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	

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Dialysis Machine

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters				
ADS1115	Delta-Sigma ADC	16 bit, 860SPS, 4 SE, 2 Diff input, PGA, MUX, Comparator, V_{REF}	Smallest 16-bit ADC – 2.0 x 1.5 x .04mm leadless QFN pkg – reduces system size and component count	ADS1013/14/15/ ADS1113/14/
ADS1251	Delta-Sigma ADC	24-bit, 20kSPS, 7.5mW power, 1.5ppm low noise	Precision, wide dynamic range	ADS1252/53/58
ADS7866	SAR ADC, Serial	1.2V, 12-bit, 200kSPS (max), 85dB SFDR	Very small, low power	
ADS7924	Micropower SAR ADC	12-bit, 100kSPS, 4 channel, ≤1µA power down current, I^2C interface, QFN package	Intelleigent system power management and self monitoring	
ADS7951	SAR ADC	12-bit, 8-channel, 1MSPS, SPI interface w/threshold alarms, QFN package	Low power, small package, and excellent performance	ADS7955, ADS7959
ADS8201	Low-Power SAR ADC	8 channel, 12-bit, 100kSPS, 1.32mW power consumption at 100kSPS	Full on-chip data acquisition system	ADS7870
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
ADS8326	SAR ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL, SE input	Low power, small package, and wide supply range	ADS8317
DAC8806	Multiplying DAC	14-bit, 0.5µs settling time, 2MSPS update rate, parallel interface, 2.7V to 5.5V supply	Low noise, low power	DAC7742
DAC8811	Multiplying DAC	16-bit, serial input, 0.5µs settling time, 2MSPS update rate, 0.025mW power	Low noise, low power	DAC7811, DAC8801
DAC8820	Multiplying DAC	16-bit, parallel input, 0.5µs settling time, 2MSPS update rate, 0.025mW power, current output	Parallel interface for high-speed communications	DAC7541, DAC8806
Processors				
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	
TMS320F28022	Low-End 32-Bit MCU with Analog Integration	Small packages, integration, real-time control performance	System cost optimization	F2802x Piccolo™ Series
TMS320F28032	Mid-End 32-Bit MCU with Analog Integration	Integration, up to 128KB Flash, control-law accelerator, real-time control performance	System cost optimization, performance at lower power	F2803x Piccolo Series
TMS320F2808	Mid-End 32-Bit MCU	Integration, 12 derivatives pin-to-pin compatible from 60MHz to 100Hz, real-time control performance	System cost optimization, scalability in design	F280x derivatives series
TMS320F28234	High-End 32-Bit Fixed-Point MCU	Integration, performances, pin-to-pin compatibility with floating point	Room for performance and application evolution	F28232, F28235
TMS320F28334	High-End 32-Bit Floating-Point MCU	Integration, performances, unique pin-to-pin compatibility with fixed point, supports both fixed and floating	Ease of development, room for performance and software evolution	F28332, F28335

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Infusion Pump

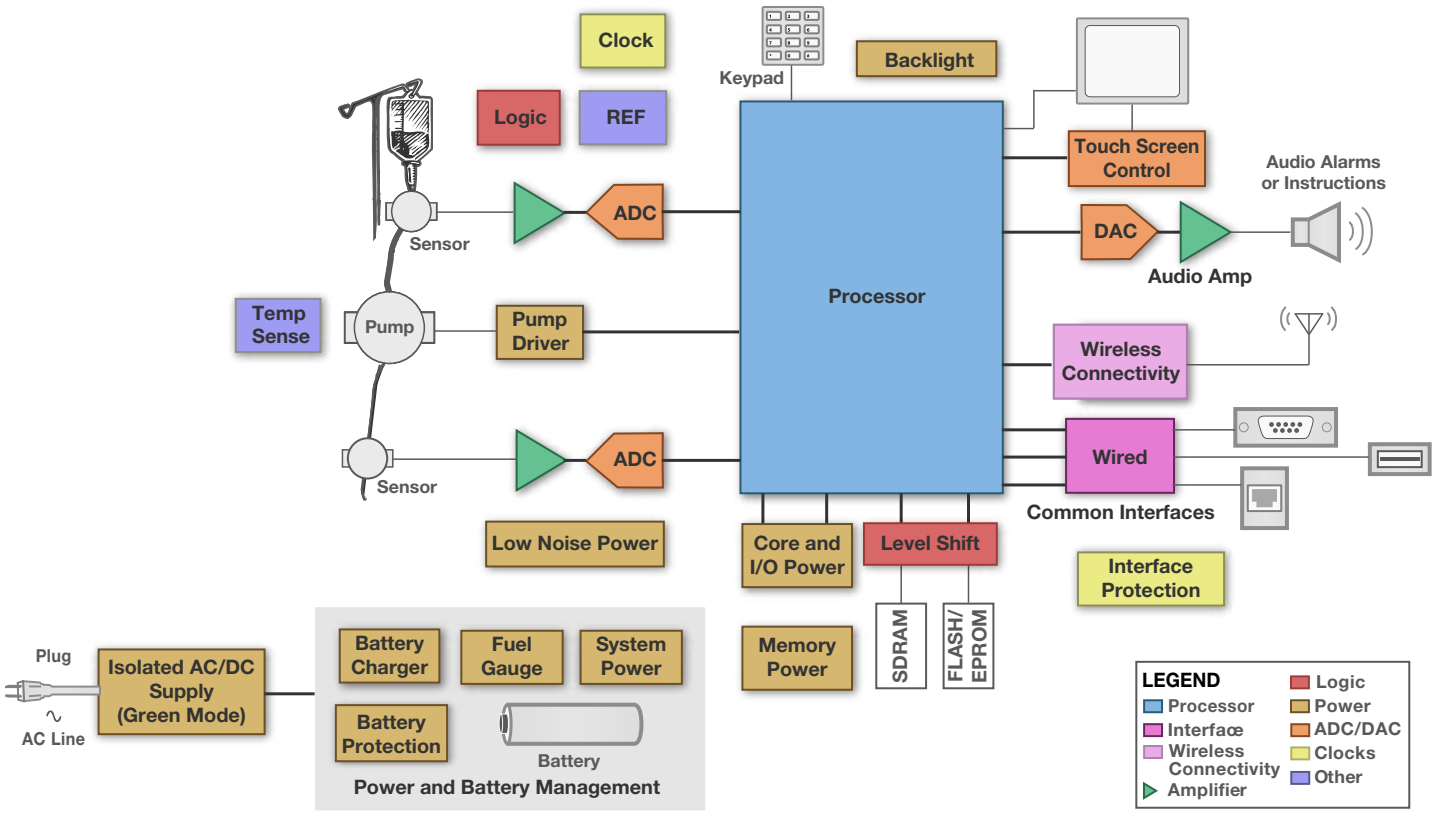
Infusion pumps are an effective pathway to deliver fluid, blood, and medication to a patient's vital organs. Since the entire blood supply within a human body circulates within 60 seconds, substances introduced into the circulatory system are distributed rapidly.

An infusion device typically consists of three major components: the fluid reservoir, a catheter system for transferring fluids into the body and a device that combines electronics with a mechanism to generate and regulate flow. Regulated drug concentration in the body is needed to achieve and maintain a desired result, especially if prolonged under-infusion or over-infusion takes place. While under-infusion may not require sufficient therapy, over-infusion can produce more serious toxic side effects.

The infusion of drugs requires high flow-rate accuracy and flow uniformity. Sensors can be used to count the number of drops passing through the drip chamber. Sensors can also provide flow feedback for automatic rate adjustment and detect downstream occlusions below the pumping mechanism. However, flow-rate accuracy remains limited by the rate and viscosity of the drip as well as improper angulation if in motion. Flow uniformity can also suffer at low flow rates from the discrete nature of the drop detector.

Despite these limitations, a processor with an advanced graphical user interface, smart and real-time physiological processing and wired and wireless connectivity options for patient monitoring and data logging applications provide an additional level of safety by quickly detecting complications and generating an alarm.

One alternative to the drop sensor is a volumetric metering chamber. A pump with a stepper or servo-controlled DC motor can be used to provide the driving force for the fluid by mechanized displacement of the contents in the volumetric chamber. The stepping resolution, along with chamber elasticity, can influence flow uniformity. When the volume is not uniform over the mechanism's cycle, software control can be used to compensate for the variation.



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Infusion pump system block diagram.

Infusion Pump

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
OPA211	Precision Op Amp	1.1nV/√Hz noise at 1kHz, ±2.25V to ±18V supply, 80MHz BW	Unity gain stable, RRO, wide supply range	OPA227
OPA365	Op Amp	Zero crossover, 0.0006% THD+N, 100dB CMRR, RRIO, 4.5nV/√Hz noise, 50MHz GBW, 200µV input offset	Superior performance, excellent for driving single-supply ADCs	OPA333, OPA211
OPA376	Precision Op Amp	7.5nV/√Hz noise, 760µA(typ)/ch Iq, 5µV (typ) offset, input EMI filter, RRO	Low noise, low power, low input bias	OPA340, OPA337
OPA378	Op Amp	0.4μV_{PP} low noise, 125µA (typ) quiescent current, 0.15µV offset voltage, 2.2V to 5V supply	microPower, rail-to-rail I/O, excellent PSRR	OPA330, OPA333, OPA335
OPA827	Precision JFET Op Amp	4nV/√Hz noise at 1kHz, ±4V to ±18V supply, 15pA (typ) input bias current, 22MHz BW	High precision, low noise, low input bias, wide supply range	OPA177, OPA627, OPA132, OPA141
INA118	Instrumentation Amp	110dB CMRR, 5nA (max) bias current, 50µV (max) offset	Wide BW at high gains, ±1.35V to ±18V supply	INA128, INA822
INA333	Instrumentation Amp	20µV (max) offset, 50nV/°C drift, 200pA input bias	Low power, low drift, tiny package	INA326
TPA2006D1	Analog-Input Class-D Amp	1.45W mono, filter-free Class D, 1.8V shutdown		
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA2016D2	Analog-Input Class-D Amp	1.7W stereo, Class D with dynamic range compression and automatic gain control		
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	
THS4521	Low power FDA	1.14mA (typ) quiescent current, low distortion, 4.6nV/√Hz voltage noise	Low power, high accuracy	THS4522, THS4524
Data Converters				
ADS1258	Delta-Sigma ADC	16-channel, 24-bit, 125kSPS, 23.7kSPS/channel	Fastest multi-channel, delta-sigma ADC, measures all 16 inputs in <675µs	ADS1256, ADS1255, ADS8344, ADS1158
ADS7952	SAR ADC	12-bit, 1MSPS, 70dB SNR, 11.5mW power	Zero latency, ideal for multi-channel systems	ADS7951, ADS7953
ADS8317	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Excellent linearity, micropower, high speed	ADS8422
ADS8318	High-Speed SAR	16-bit, 500kSPS, 18mW at 500kSPS power, ±1 LSB INL	Precision, excellent AC/DC performance	
ADS8326	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Low noise, low power, high speed	ADS8325
ADS8331/32	SAR ADC	16-bit, 500kSPS, 4/8 channels, with serial interface	Mux out feature can be used to reduce system part count and overall cost	ADS8342
ADS8472	SAR ADC	16-bit, 1MSPS, ±0.4LSB (typ) INL	Zero latency, low power	
TLV320DAC3120	Low-Power Audio DAC	Mono DAC with 2.5W mono Class-D speaker amplifier; miniDSP for audio processing	Longer battery life, better audio quality, lower cost	TLV320DAC3101
TLV320DAC32	Audio DAC	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		

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Infusion Pump

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
MSP430F44x	Ultra-Low-Power 16-Bit MCU	32KB to 60KB Flash, 1KB/2KB RAM, 8-channel 12-bit ADC, comparator, 2x SPI + UART, SVS, 160-segment LCD controller	Ultra-low-power, integrated analog peripherals, hardware communication channels	
MSP430FG461x	Ultra-Low-Power 16-Bit MCU	92KB to 120KB Flash, 4KB/8KB RAM, 12-channel 12-bit ADC, dual 12-bit DAC, comparator, 3 op amps, 3-channel DMA, SPI + UART, USCI, SVS, 160-segment LCD controller	Ultra-low-power signal-chain-on-chip (SCoC), configurable op amps, multiple hardware communication channels	MSP430FG43x
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
OMAP3530	Applications Processor	ARM® Cortex-A8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at handheld power levels	OMAP3503, OMAP3515, OMAP3525
OMAP-L137	Low-Power Application Processor	300MHz ARM9™ w/MMU + 300MHz C674x™ floating-point DSP core, rich peripheral set including 10/100 Ethernet MAC, LCD controller, USB 2.0 HS OTG, USB 1.1 full speed, SPI and MMC/SD	Highly integrated, dual-core solution drives low system cost and maximum flexibility for connectivity, GUI, and high-level OS options. Extends product battery life by providing greater than 60% power reduction over existing solutions in the market.	OMAP-L138
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex--M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	
TMS320F28022	Low-End 32-Bit MCU with Analog Integration	Small packages, integration, real-time control performance	System cost optimization	F2802x Piccolo™ series
TMS320F28032	Mid-End 32-Bit MCU with Analog Integration	Integration, up to 128KB Flash, control-law accelerator, real-time control performance	System cost optimization, performance at lower power	F2803x Piccolo series
Hercules RM48x	Safety Microcontroller	Up to 220MHz Dual Lockstep ARM® Cortex-R4 CPUs with Floating Point, up to 3MB Flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	

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Automated External Defibrillator (AED)

The automated external defibrillator (AED) is a highly sophisticated microprocessor-based device that monitors, assesses and automatically treats patients with life-threatening heart rhythms. It captures ECG signals from the therapy electrodes, runs an ECG-analysis algorithm to identify shockable rhythms, and then advises the operator about whether defibrillation is necessary. A basic defibrillator contains a high-voltage power supply, storage capacitor, optional inductor, and patient electrodes (see block diagram). It develops an electrical charge in the capacitor to a certain voltage, creating the potential for current flow. The higher the voltage, the more current can potentially flow. The AED outputs audio instructions and visual prompts to guide the operator through the defibrillation procedure. In a typical defibrillation sequence, the AED provides voice prompts to instruct the user to attach the patient electrodes and starts acquiring ECG data. If the AED analyzes the patient's ECG and detects a shockable rhythm, the capacitor is charged according to energy stored in the capacitor, $W_c = \frac{1}{2}CV_c^2$; and capacitor voltage, $V_{c(t)} = V_{c(0)}e^{-t/RC}$, where R = R(lead) << R(chest).

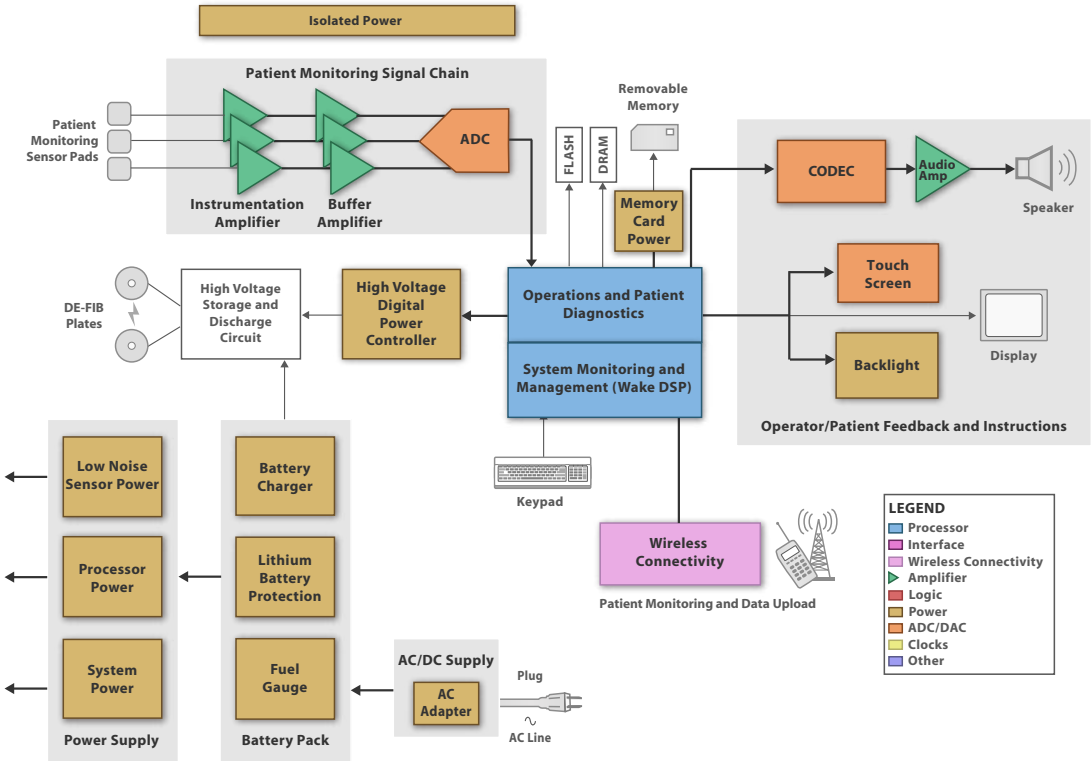
Then, following the instructions, the operator presses the shock button to deliver the high-voltage pulse; so current begins flowing through the body to depolarize most of the heart cells, which often re-establishes coordinated contractions and normal rhythm. The amount of flowing current is determined by the capacitor and body impedance. The accompanying graph shows the level of current and the length of time the current flows through the body.

Many jurisdictions and medical directors also require that the AED record the audio from the scene of a cardiac arrest for post-event analysis. All AEDs include a means to store and retrieve patient ECG patterns.

The front-end signals of the AED come from the ECG electrodes placed on the patient, which requires an instrumentation amplifier to amplify its very small amplitude (<10mV). The instrumentation amplifiers INA118/INA128/INA333 are designed to have:

- Capability to sense low-amplitude signals from 0.1mV to 10mV,
- Very high input impedance (>5MΩ),
- Very low input leakage current (<1μA),
- Flat frequency response of 0.1Hz to 100Hz and
- High common-mode rejection ratio (CMRR) (>100dB).

The other front-end signal of the AED is the microphone input for recording the audio from the scene of a cardiac arrest. Both ECG and microphone input are digitized and processed by a DSP. Most AED designs use a 16-bit processor and therefore work well with 16-bit ADCs to digitize ECG and voice input. The amplified ECG signal has

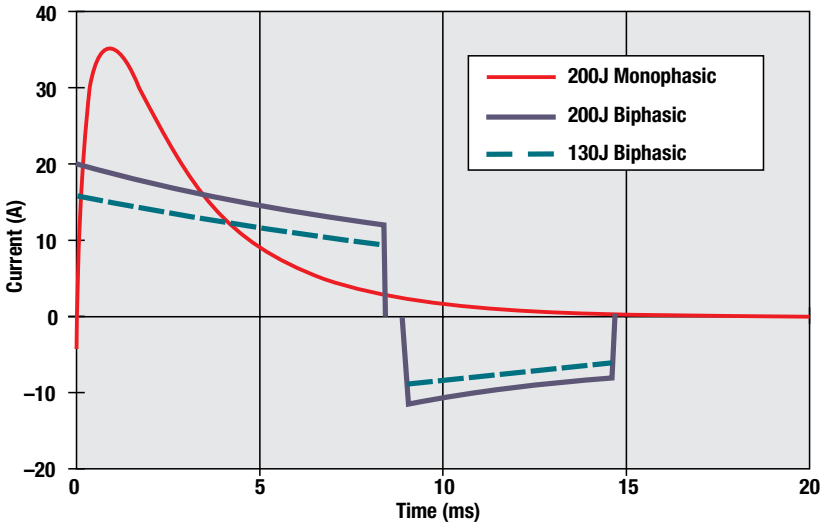


Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

AED system block diagram.

Automated External Defibrillator (AED)

a bandwidth of 0.1Hz to 100Hz and requires a minimum SNR of 50dB. The audio recording/playback signal typically has a bandwidth of 8kHz and requires a minimum SNR of 65dB. The microphone input also needs to be amplified with a maximum programmable gain of 40dB. The AED can have synthesized audio instruction with volume control output to either the headphone speaker or the 8Ω speaker. System designers will find that the TLV320AIC20K makes the AED front-end digitization very easy and simple because it integrates two ADCs, two DACs, a microphone amplifier, a headphone driver and an 8Ω driver with volume control; and it can be seamlessly interfaced to a DSP.



Typical AED drive current. AEDs can deliver either monophasic or biphasic defibrillation waveforms to the heart. Monophasic delivers a current that travels in one direction throughout the shock. Newer biphasic technology allows the current to be reversed partway through the shock thus potentially lessening the risk of burns and myocardial damage.

Single-Supply, microPower, RRO, CMOS Instrumentation Amplifier

INA321

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/ina321**

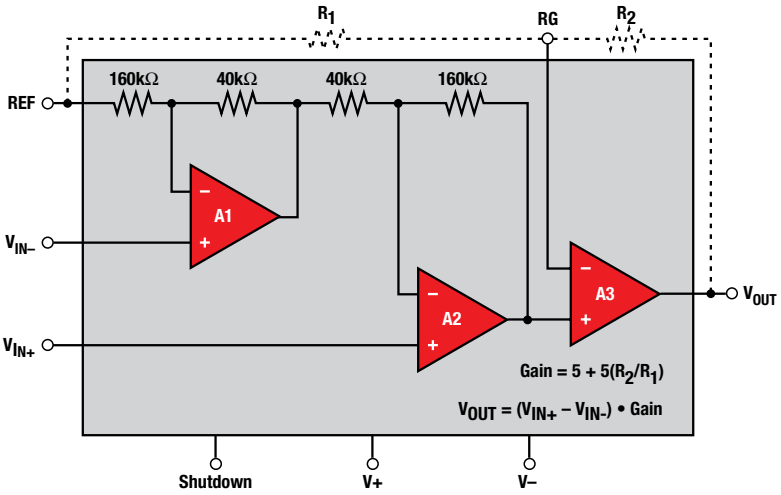
Key Features

- Low quiescent current: 40µA/ch
- High gain accuracy: 2ppm/°C, 0.02%, G = 5
- Low offset voltage: ±200µV
- High CMRR: 94dB
- Low bias current: 10pA
- Bandwidth: 500kHz, G = 5V/V
- Gain set with external resistors
- Packaging: MSOP-8 (single); TSSOP-14 (dual)

Applications

- Physiological amplifier: ECG, EEG, EMG
- Test equipment
- Differential line receivers with gain
- Industrial sensor amplifier: bridge, RTD, thermistor, position

The INA321 is a rail-to-rail output, CMOS instrumentation amp that provides amplification of differential signals with microPower current consumption of 40µA. It features <1µA current consumption in standby mode and returns to normal operation in microseconds making it a good choice for low-power battery or multiplexing applications. Configured internally for 5V/V gain, the INA321 offers exceptional flexibility with user-programmable external gain resistors. It reduces common-mode error over frequency and with CMRR remaining high up to 3kHz, line noise and line harmonics are rejected.



INA321 functional block diagram.

Automated External Defibrillator (AED)

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
INA118	Instrumentation Amp	110dB CMRR, 5nA (max) bias current, 50µV (max) offset	Wide BW at high gains, ±1.35V to ±18V supply	INA128
INA128	Instrumentation Amp	50µV offset voltage, drift (0.5µV/°C) and high common-mode rejection (120dB at G ≥ 100)	Wide BW at high gains	INA129
INA321	CMOS Instrumentation Amp	0.02% accuracy, 2ppm/°C drift for gain=5; 10pA input bias current	High gain accuracy	INA2321 (dual)
INA333	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA326
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA333	Precision Op Amp	1.8V min supply, 0.017mA/ch (max), 10µV offset (max), 0.05 µV/°C drift (max)	Zero drift, high precision, low power, EMI input	OPA335, OPA378, OPA330
OPA369	Zero-Crossover Amp	1.8V, 700nA, RRIO, 114dB CMMR, 0.4µV/°C drift	Low power, unmatched DC precision	OPA379, OPA2369 (dual)
LPV521	Nano Power Amplifier	1.6V, 345nA, RRIO, 120dB CMRR, 0.4µV/°C drift	Lowest power, high CMRR	LPV511, OPA369
TPA2005D1	Analog-Input Class-D Amp	1.4W mono, fully differential, filter-free Class D	Loud audio, long battery life	TPA2006D1
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA3007D1	Analog-Input Class-D Amp	Mono, medium power, filter-free Class D		
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB, 1.8V shutdown	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	
THS452x	Low power FDA	1.14mA (typ) quiescent current,+2.5V to 5.5V supply	Low power, single and dula supply, low distortion	THS4522, THS4524
Data Converters				
ADS1115	Delta-Sigma ADC	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC, 2.0 x 1.5 x .04mm leadless WFN pkg; reduces system size and componenent count	ADS1113/4, ADS1013/14/15
ADS1298	ECG/EEG AFE	24-bit, 8 PGA, 8 ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1294, ADS1296, ADS1198, ADS1251/58
ADS7866	SAR ADC, Serial	1.2V, 12-bit, 200kSPS (max), 85dB SFDR		ADS7924, ADS8201
ADS8317	SAR ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL, differential input	Low power, small package, and wide supply range	ADS8326
ADS8326	Low-Power ADC	16-bit, 250kSPS, 2.7V to 5.5V supply, ±1.5 LSB (max) INL	Small package, wide supply range	
ADS8331/32	SAR ADC	16-bit, 500kSPS, 4/8 channels, with serial interface	Mux out feature can be used to reduce system part count and overall cost	ADS8342
MSC1210	Data Acq. System	Enhanced 8051 core w/Flash memory and 24-bit ADC		
TLV320AIC12K	Audio Codec	Low-power, mono, voice-band codec with 8Ω speaker amp		
TLV320AIC20K	Audio Codec	Low-power, stereo, voice-band codec with 8Ω speaker amp	Fully compatible with TMS320C54x™ DSP power supplies	TLV320AIC24K
TLV320AIC3104	Audio Codec	Low-power stereo codec, 6 inputs, 6 outputs, headphone amp, enhanced digital effects		
TLV320DAC3120	Low-Power Audio DAC	Mono DAC with 2.5W mono Class-D speaker amplifier; miniDSP for audio processing	Longer battery life, better audio quality, lower cost	TLV320DAC3101
TLV320DAC32	Audio Converter	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		
TSC2003	Touch-Screen Controller	I^2C interface for standard, fast, high-speed modes	Direct battery measurement	ADS7845, TSC2000, TSC2007
TSC2046	Touch-Screen Controller	Low voltage I/O, touch-pressure measurement, 2.2V to 5.2V operation	QSPI™ and SP™ 3-wire interface	

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Automated External Defibrillator (AED)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF30xx	Low-Power, Low-Drift Series Reference	50µA, 0.2% initial accuracy, 50ppm/°C max drift, ±25mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V		REF31xx, REF33xx, REF29xx
REF31xx	Series Voltage	0.2% (max) initial accuracy, 15ppm/°C (max) drift, 100µA 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Low power consumption for portable applications	REF3120, REF3125, REF3133
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Processors				
REF32xx	Ultra-Low-Drift Series Reference	100µA, 0.2% initial accuracy, 7ppm/°C max drift, ±10mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Improves system accuracy	
REF33xx	Very-Low-Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF50xx	High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V	Improves system accuracy	REF02
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
MSP430F20xx	Ultra-Low-Power 16-Bit MCU	1KB/2KB Flash, 128B RAM, SPI+I^2C	8 ch. 12-bit ADC or 4 ch. 16-bit SD ADC, 4 x 4mm package	
MSP430F22x4	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 512B/1KB RAM, SPI + I^2C + UART/LIN + IrDA	12 ch. 10-bit ADC, 2 op amps	
MSP430F23x0	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 1KB/2KB RAM, SPI + I^2C + UART/LIN + IrDA	Analog comparator, HW multiplier	
MSP430F41x	Ultra-Low-Power 16-Bit MCU	4 to 32KB Flash, 256B to 1KB RAM, SVS, 96 segment LCD	Analog comparator	
MSP430F42x	Ultra-Low-Power 16-Bit MCU	8 to 32KB Flash, 256B to 1KB RAM, SPI + UART, SVS, 128 segment LCD	3 x 16-bit SD ADC	
MSP430F42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC	
MSP430F43x	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 512B/1KB RAM, SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, analog comparator	
MSP430F44x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, 2x SPI + UART, SVS, 160 segment LCD	8 ch. 12-bit ADC, HW multiplier	
MSP430F47xx	Ultra-Low-Power 16-Bit MCU	60KB Flash, 256B RAM, (4) USCI, 160 segment LCD	(4) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F241x	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, temp. sensor	8 ch. 12-bit ADC, analog comparator, HW multiplier	
MSP430F261x	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, SVS, DMA, temp. sensor	Analog comparator, 2 ch. 12-bit DAC, 8 ch. 12-bit ADC, HW multiplier	
MSP430F471xx	Ultra-Low-Power 16-Bit MCU	120KB Flash, 8KB RAM, (4) USCI, DMA, 160 segment LCD	(7) SD16 ADC, HW multiplier, temp. sensor, analog comparator	
MSP430F54xxA	Ultra-Low-Power 16-Bit MCU	128 to 256KB Flash, 16KB RAM, (4) USCI, PMM, DMA, temp. sensor	16 ch. 12-bit ADC, analog comparator, RTC, internal voltage regulator for power optimization	
MSP430FG42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD	5 ch. 16-bit SD ADC, 12-bit DAC, 2 integrated op amps	
MSP430FG43x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
MSP430FG461x	Ultra-Low-Power 16-Bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD	12 ch.12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amps, HW multiplier	
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703

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Automated External Defibrillator (AED)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
Tiva™ C Series TM4C123x	Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
TMS320C5000™	DSP	Power efficient, high performance	Fixed-point DSP with industry's best combination of standby and dynamic power consumption	
TMS320VC5506	DSP	200MHz, dual MAC, very low standby power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320V5509A, TMS320V5502
RF Transceivers				
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, Broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, Broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	

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Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
DRV104	PWM High-Side Driver Amp for Solenoids, Coils	1.2A output drive, +8V to +32V supply range	PWM operation conserves power and allows for fine control	DRV102, DRV101
INA159	High-Speed, Precision Gain Level Translation Difference Amp	Gain of 0.2 to interface ±10V signals to single-supply ADCs	Maintains gain accuracy and common-mode rejection over temperature	
INA333	Low Power, Precision Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA118, INA326
OPA211	Precision Op-Amp	1.1nV/$\sqrt{Hz}$ at 1kHz low noise, 0.2µV/°C offset drift, 80MHz (G = 100) BW	<1µs settling time to 16-bit accuracy	
OPA277	Precision Op-Amp	10µV offset voltage, ±0.1µV/°C low drift, 134dB open-loop gain, 140dB CMRR	Available in S, D, Q	OPA177, OPA627
OPA380	Transimpedance Amp	90MHz GBW, over 1MHz transimpedance BW, 25µV offset (max), 0.1µV/°C drift (max)	Precision, dynamic range 4 to 5 decades, excellent long term stability	OPA350, OPA335
OPA735	CMOS Op-Amp	0.05µV/°C zero drift (max), 750µA IQ (max), 5µV offset voltage	Zero-drift series, dual version available	OPA734
OPA827	JFET-Input Op-Amp	1µV/°C drift, 4.5mA/ch IQ, 250µV offset voltage, 18MHz BW	Outstanding DC precision w/excellent AC performance	OPA141
PGA309	Prog. Sensor Conditioner	Sensor error compensation: span, offset, temp drifts	Complete bridge sensor conditioner	PGA308
THS4520	High-Speed Op-Amp	450MHz (G = 2V/V), 570V/µs SR, 2nV/$\sqrt{Hz}$ noise (f>10MHz)	Single-to-differential conversion	
THS4131	High-Speed Op-Amp	150MHz (–3dB) BW, 51V/µs SR, –100dB HD3 at 250kHz	Low noise, fully differential I/O	
THS4631	High-Speed Op-Amp	210MHz GBW, 900V/µs (G = 2) SR, –76dB SFDR at 5MHz	±5 and ±15V supply operation, 95mA output current	
Data Converters				
ADS1115	Delta-Sigma ADC	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC – 2.0 x 1.5 x .04mm leadless QFN pkg – reduces system size/component count	ADS1113/4, ADS1013/14/15
ADS1248	Delta-Sigma ADC	24-bit, 2kSPS, 7 channels w/dual current sources, GPIO, low drift V_{REF}, and temp sensor	Flexible front end for flow or temperature measurement	ADS1148, ADS1247, ADS1147
ADS1258	Delta-Sigma ADC	16-channel, 24-bit, 125kSPS, 23.7kSPS/channel	Fastest multichannel delta-sigma ADC, measures all 16 inputs in <675µs	ADS1274, ADS1278, ADS1605, ADS1602, ADS1601
ADS1278	Delta-Sigma ADC	24-bit, 128kSPS, 8-channel, 111dB SNR	Simultaneous measurement, onboard decimation filter	ADS1271, ADS1274
ADS1293	ECG/EEG AFE	24-bit, 3 PGA, 3 ADC, plus RLD, very low power	Very low power AFE. Flexible for 1,2,3,5,6,7,8,12 lead battery powered applications.	ADS1292,ADS1294
ADS1298	ECG/EEG AFE	24-bit, 8PGA, 8ADC, plus RLD and RESP	Complete front end, reduction in power and size, increase reliability	ADS1294, ADS1296, ADS1198, ADS1251/58
ADS1610	Delta-Sigma ADC	16-bit, 10MSPS, parallel interface	SYNC pin for simultaneous sampling	ADS1605
ADS7861	SAR ADC	Dual, 500kHz, 12-bit 2+2ch	Simultaneous sampling	ADS7864, ADS8361, ADS8364
ADS8254/55	SAR ADC	16-bit, 1MSPS, 98dB (typ) SNR, 270mW power, onboard 4V int reference, driver amp and MUX	Flexible input configuration, multichannel modes	
ADS8284/85	SAR ADC	18-bit, 1MSPS, 98dB (typ) SNR, 270mW power, onboard 4V int reference, driver amp and MUX	Flexible input configuration, multichannel modes	
ADS8317	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Excellent linearity, micropower, high speed	ADS8422
ADS8326	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Low noise, low power, high speed	ADS8325
ADS8410	SAR ADC	16-bit, 2MHz, 87.5dB at 10kHz I/P SNR, int. ref.	200Mbps LVDS serial interface	ADS8413
ADS8413	SAR ADC	16-bit, 2MSPS, LVDS interface int. ref. and buffer	LVDS, serial interface, daisy-chain capable	ADS8410, ADS8406
ADS8422	SAR ADC	16-bit, 4MSPS, 1 LSB INL (typ), parallel interface	Zero latency	ADS8412, ADS8472
ADS8556	SAR ADC	16-bit, 6-channel, ±1V to ±12V input configuration	Six SAR ADCs grouped in 3 pairs, pin selectable input range	ADS8557, ADS8558
DAC7811	Multiplying DAC	12-bit, single channel, serial input, multiplying DAC	Multiplying, current output	DAC7613, DAC8811, DAC8871
DAC8550/2/4	Low-Power DAC	16-bit, 1-4 chs, ±3 LSB (typ) INL, 0.1 to 0.15nV-s glitch	Excellent AC/DC performance	DAC8560, ADS8564
DAC8560	V_{OUT} DAC	16-bit, 0.15nV-s glitch, ±10µs to 0.003% FSR settling time	Small package, low power	DAC7731, DAC8411
DAC8564/5/8	Quad DAC	16-bit, 2.5V V_{REF}, 2ppm/°C drift, 0.15nV-s glitch	Quad and octal versions	DAC8551
DAC8812	MDAC	16-bit, ±1-LSB INL, –105dB THD, 0.5µs settling time	Multiplying, current output	DAC8814
DAC8814	Multiplying DAC	16-bit, 0.5µs settling time, –105dB THD, 1 LSB (max) relative accuracy	Double-buffered serial data interface	DAC7715, DAC8811

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters (Continued)				
DAC8820	DAC	16-bit, parallel input multiplying, ±1.5 LSB DNL, ±1 LSB INL	2.7V to 5.5V supply, low noise, low power	DAC8814, DAC8822
TPDxE001	ESD Protection	Industry's lowest leakage spec, 15kV ESD solution in two-, three-, four- and six-channel packages	System-level ESD protection for USB 2.0, Ethernet, analog I/O interfaces	TPDxE004
TPDxF003	EMI Filter	–3dB bandwidth at 200MHz, 15kV contact ESD, and four-, six- and eight-channel available	System-level EMI immunity for high-speed data interface	TPD6F002
TPD2E007	ESD Protection	Back-to-back clamp for bipolar signal interface	System-level ESD protection for RS485, RS422, RS232, LVDS, and CAN interfaces	
TPD4S009	ESD Protection	Industry's lowest leakage spec, less than 0.05pF differential capacitance	System-level ESD protection for HDMI, eSATA, USB 2.0, and DisplayPort high-speed interfaces	TPD2E009, TPD8S009, TPD4S010
TXS0102	Autodirection Sensing Voltage-Level Translator	2-bit, 1.2V to 5.5V, works with push-pull and open drain (e.g. I²C) drivers	Bridges incompatible digital switching voltages	TXS010x, TXB010x, SN74AVCxxT245
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
TM4C123x	Tiva™ C Series ARM® Microcontroller	ARM® Cortex-M4, floating-point performance, up to 256KB Flash, USB, advanced motion control, and advanced system control, with up to 16 PWM outputs and a generous number of serial communication peripherals	12-bit ADC, delivers connectivity, higher performance integration and lower power consumption	
MSP430FG461x	Microcontroller	Ultra-low power, 16-bit operation, up to 120kB flash, up to 8kB RAM, 12-bit ADC, 12-bit DAC, three op-amps, LCD controller	Ultra-low-power, integrated SoC	
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
OMAP3530	Digital Signal Processor	Low power 64x + ARM® Cortex-A8 CPU, 3440 MMACS, 720MHz	PowerVR SGX graphics accelerator, HD resolution output	OMAP3525, OMAP3515, OMAP3503
TMS320F2803x	Microcontroller	32-bit operation, 60MHz, up to 128kB flash, up to 20kB RAM, high-speed 12-bit ADC, high-resolution PWM	ADC capable of 5MSPS, programmable CLA (control law accelerator)	
Hercules RM48x	32-Bit Floating-Point Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB flash w/ECC, up to 256KB RAM w/ ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
Interface				
TPDxE001	ESD Protection	Industry's lowest leakage spec, 15kV ESD solution in two-, three-, four- and six-channel packages	System-level ESD protection for USB 2.0, Ethernet, analog I/O interfaces	TPDxE004
TPDxF003	EMI Filter	–3dB bandwidth at 200MHz, 15kV contact ESD, and four-, six- and eight-channel available	System-level EMI immunity for high-speed data interface	TPD6F002
TPD2E007	ESD Protection	Back-to-back clamp for bipolar signal interface	System-level ESD protection for RS485, RS422, RS232, LVDS, and CAN interfaces	
TPD4S009	ESD Protection	Industry's lowest leakage spec, less than 0.05pF differential capacitance	System-level ESD protection for HDMI, eSATA, USB 2.0, and DisplayPort high-speed interfaces	TPD2E009, TPD8S009, TPD4S010
TXS0102	Autodirection Sensing Voltage-Level Translator	2-bit, 1.2V to 5.5V, works with push-pull and open drain (e.g. I²C) drivers	Bridges incompatible digital switching voltages	TXS010x, TXB010x, SN74AVCxxT245
Clocking Products				
CDCE(L)9xx	1.8V Programmable VCXO Multi-PLL Clock Synthesizer	LVCMOS or Xtal Inputs; VCXO Input with ±150ppm (typ) pulling range	Low power consumption, low jitter, low skew; EEPROM programmable	CDCE706, CDCE906
CDCE72010	2:10 Ultra-Low Jitter Cleaner w/ VCXO	Wide-range integer divide; <35fs RMS jitter; on-chip EEPROM	Wide input/output freq. range supports high and low end of freq. standards	CDCE6200x
CDCM6100x	1:4/2/1 Xtal-In 44MHz - 683MHz Clock Generator	Fully integrated VCO and loop filter generates various frequencies; <1ps RMS jitter	One single device across multiple designs, replacing up to four discrete XOs	
CDCS50x	Xtal-In Clock Generator with Optional SSC	Selectable multiplier rates of 1x and 4x; selectable spread-spectrum modulation	Reduces EMI up to 10dB; replaces more costly crystal oscillators	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC1120	Sub-1GHz RF Transceiver	Industry leading RF blocking and selectivity: 65dB adjacent channel rejection at 12.5kHz offset 90dB blocking. High output power (up to +16dBm) and excellent sensitivity (–123dBm @1.2kbps). WaveMatch; Advanced DSP sync detector with high sensitivity and strong noise immunity.	The most robust RF transceiver on the market. Reliable communication in presence of RF interference. Up to 139dB RF link budget. More reliable links, no false sync detects in noise. Enables RF sniff mode with <3mA current consumption.	
CC2520	2.4GHz ZigBee®/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temperature range; AES-128 security module	Reliable RF link with interference present; 400m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	CC2530
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC2530/31	Second Gen. System-on-Chip Solution for 2.4GHz IEEE 802.15.4/RF4CE/ ZigBee®	Excellent RX sensitivity, low power, easy to use development tools	RF design system-on-chip for quick time to market. Provides a robust and complete ZigBee® USB dongle or firmware-upgradable network node.	CC2590/91, CC2530ZNP
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class system-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	
Toolkits				
DLP® Discovery™ 4100	An optical semi-conductor module that allows digital manipulation of light	±12° mirror operation, works with Visible, UV and near-IR light	This device can surpass the speed, precision and efficiency of other spatial light modulators	DLP® Pico™
DLP® LightCrafter™	A compact, versatile EVM for integrating light into medical applications	608 x 684 micromirror array, 7.6µm micromirror pitch, pattern rates up to 4000Hz, video display up to WVGA resolution	Has multiple industry standard interfaces including USB, mini-HDMI, and I^2C	DLP® LightCrafter™

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Overview

Imaging overview

Medical imaging technology is continually evolving and advancing, all with the goal of enabling early diagnosis, prevention, and patient comfort. Medical imaging modalities such as ultrasound, x-ray and MRI all have complex processing and performance needs that push the limits of what is possible. By developing innovative ways to increase integration, lower noise, and lower power consumption, TI components make high performance medical imaging more flexible, affordable and accessible.

Driven by the need for higher image quality, medical imaging applications require the highest performance including advanced integrated I/O and powerful data processing. Innovations often focus on integration, such as incorporating digital demodulation into the Analog Front End circuitry in order to decrease the FPGA processing load. A focus on decreasing power consumption and size also allows for the migration of hospital medical imaging equipment into field applications – effectively increasing the speed of delivery and availability of medical care worldwide.

TI features a broad array of comprehensive system block diagrams, selection tables and key design tools to help you accelerate innovation. TI HealthTech's broad portfolio, backed by the resources of the TI global enterprise, is the world's largest producer of analog and embedded processors and the single most experienced source for healthcare components in medical imaging applications.

Ultrasound

Ultrasound systems

As ultrasound equipment becomes more compact and portable, it heralds a variety of health care applications that illustrate how advances in medical technology are bringing care to patients instead of requiring them to travel. TI's analog products and embedded processors facilitate advanced ultrasound system designs with low power consumption and high performance, yielding portability with high-quality images.

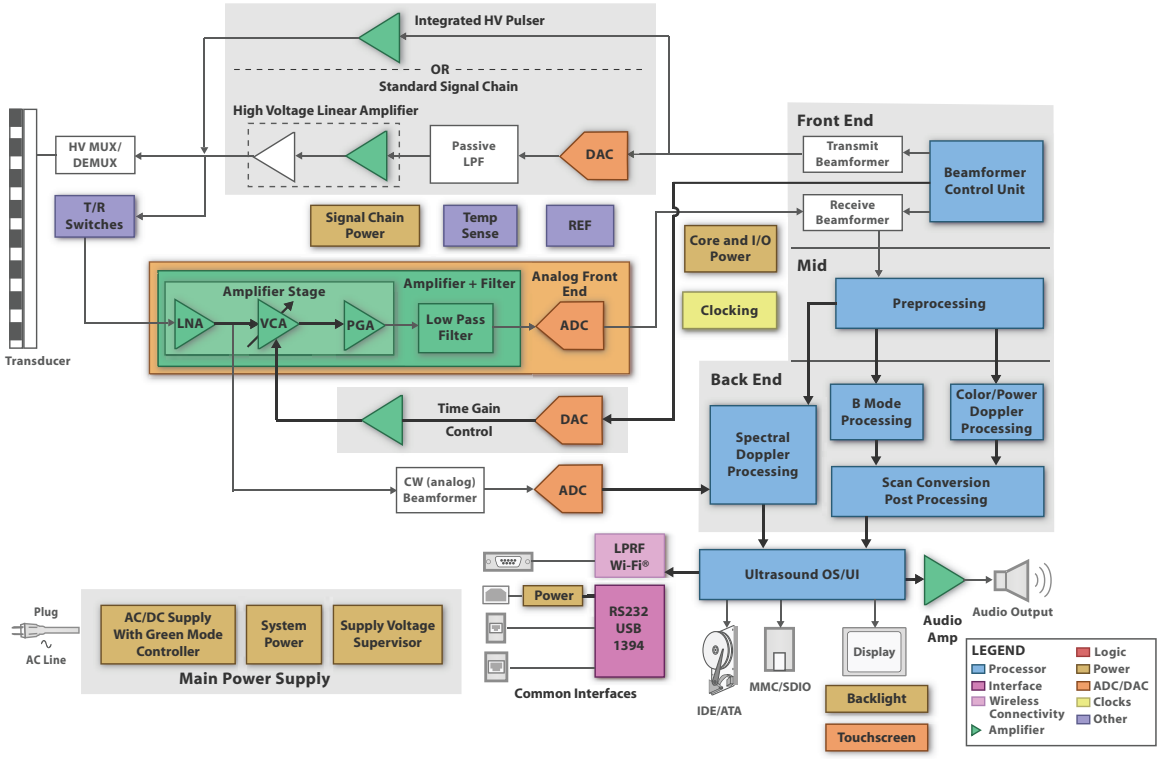
Medical and industrial ultrasound systems use focal imaging techniques to achieve imaging performance far beyond a single-channel approach. By using an array of receivers, TI's latest products for ultrasound enable high definition images through time shifting, scaling and intelligently summing echo energy. This makes it possible to focus on a single point in the scan region; by subsequently focusing on other points, an image is assembled.

When initiating a scan, a pulse is generated and transmitted from each of the eight to 512 transducer elements. These pulses are timed and scaled to illuminate a specific region of the body. After transmitting, the transducer element immediately switches into receive mode. The pulse, now in the form of mechanical energy, propagates through the body as high-frequency sound waves, typically in the range of 1 to 15MHz. As it does, the signal weakens rapidly, falling off as the square of the distance traveled. As the signal travels, portions of the wavefront energy are reflected back to the transducer/receiver.

Limits on the amount of energy that can be put into the body require that the industry develop extremely sensitive receive electronics. At focal points close to the surface, the receive echoes are strong, requiring little if any amplification. This region is referred to as the near field. At focal points deep in the body, the receive echoes will be extremely weak and must be amplified by a factor of 1,000 or more. This region is referred to as the far field. These regions represent the two extremes in which the receive electronics must operate.

In the high-gain (far field) mode, the performance limit is the sum of all noise sources in the receive chain. The two largest contributors of receive noise are the transducer/cable assembly and the receive low-noise amplifier (LNA). In the low-gain mode (near field), the performance limit is defined by the magnitude of the input signal. The ratio between these two signals defines the system's dynamic range. Many receive chains integrate the LNA with a voltage-controlled attenuator (VCA) and a programmable gain amplifier (PGA).

Ultrasound



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Ultrasound system block diagram.

Low-pass filtering is typically used between the VCA/PGA and ADC as an anti-aliasing filter and to limit the noise bandwidth. Depending on the specific system, two- to five-pole filter linear phase topologies can be found there. In selecting an op amp, the primary considerations include signal swing, minimum and maximum input frequencies, harmonic distortion, and gain requirements.

Analog-to-digital converters (ADCs) are typically 10- and 12-bit. SNR and power consumption are the most important issues, followed by channel integration. Another trend in ADCs is the implementation of an LVDS interface between the ADC and the beamformer. By serializing the data coming out of the ADC, the number of interface lines can be reduced. This reduction enables high system integration densities, which translates to smaller and lower cost PC boards — an essential part of portable imaging systems.

The front end of the digital part of the system takes in data from a number of ADCs, commonly referred to as the channel count. This number can vary from eight for ultra-portable systems to 512 for high-end devices. For 3-D and 4-D systems, this number can be even higher. The main function of the digital front end is to perform focusing at a given depth and direction. This beamforming is performed by resampling the ADC output at a higher rate, properly delaying the resampled data, multiplying by a weight (apodization factor), and then summing all the weighted and delayed outputs. Both the I/O and computational requirements for this process are extremely high.

Traditionally, FPGAs and custom ASICs have been used for digital beamforming, but today DSPs provide the ability to handle much of the required computational load. DSPs are also well suited to handle the real-time aspects of the beamforming controller, which may vary the delay and apodization profile required for beamforming based on the depth and direction of the beam.

The beamformed data is then passed through a mid-processing block where various filtering is performed to reduce noise and properly extract the ultrasound RF data. This is followed by demodulation to create complex baseband data. Adaptive processing based on the depth and angle of measurements is sometimes used to get an optimized ultrasound image.

The output from the mid-processing stage is handled in the back-end in various ways. For B-mode imaging, the data envelope is compressed to bring it to the dynamic range of the human eye. Additional image enhancement, noise reduction and speckle reduction algorithms are performed. The data is

Ultrasound

then scan converted to the final output display form and size. For Doppler processing, velocity and turbulence are estimated in the color flow mode, and power is estimated in the power Doppler mode. These estimates are again scan converted to the final output display form and size.

An assignment of color to the estimates is also necessary for proper display. In spectral Doppler mode, a windowed and overlapped FFT is taken to estimate the spectrum. It is also customary to present the Doppler data, after separation of forward and reverse flow, in the form of audio.

All of these intensive signal processing computations are well suited for DSPs.

Product portfolio for ultrasound

Analog application-specific signal chain products

- The main function of a digital front end in an ultrasound system is to focus at a given depth and direction. The AFE58xx family of fully integrated analog front ends offers compact solutions, with low power and low noise for superior image quality.
- The transmit beamformer, high-voltage (HV) pulser TIR switch, and HV multiplexer form the transmit path responsible for the pulse-excitation of transducer elements. The LM965xx family offers these functions and are designed for low power, portable solutions.

Fully Integrated 8-Channel Analog Front End with CW and Demodulation

NEW

AFE5809

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/AFE5809**

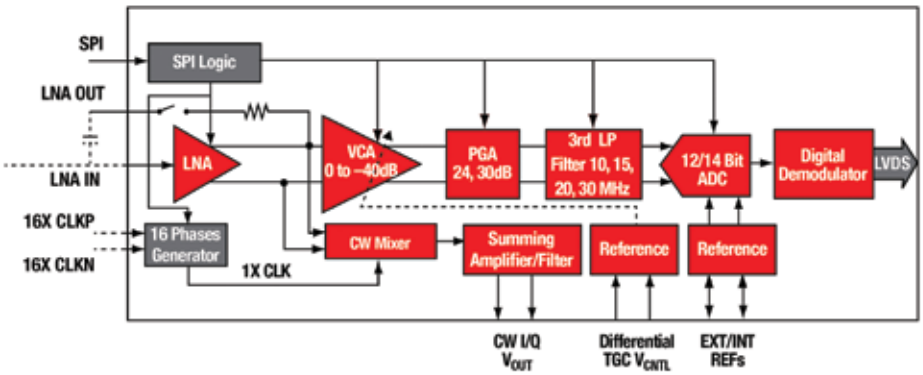
Key Features

- Digital in-phase and quadrature (I/Q) demodulator and a low-pass decimation filter to reduce the LVDS data rate and improve overall system power efficiency
- Integrated CW Doppler mixer and summing amplifier with a very low close-in phase noise better than –156dBc/Hz at 1KHz off a 2.5MHz carrier to ease design with CW beamforming
- Low-noise optimization of 0.75nV/rtHz, at 158mW/CH 65MSPS and a 14-bit ADC with 77dBFS SNR

Applications

- Ultrasound
- Non-destructive testing
- Sonar
- Radar

The AFE5809 consists of eight channels, including a low-noise amplifier, a voltage controlled attenuator, a programmable gain amplifier, a third order filter, and a 14-bit, analog-to-digital converter with LVDS output. It integrates a continuous wave Doppler mixer enabling ease of design for Spectral Doppler systems to measure blood flow velocity. The integrated CW mixer for CW beamforming has a very low close-in phase noise better than –156dBc/Hz at 1KHz off a 2.5MHz carrier. AFE5809 also includes a digital in-phase and quadrature (I/Q) demodulator and a low-pass decimation filter. The main purpose of the demodulation block is to reduce the LVDS data rate and improve overall system power efficiency. The I/Q demodulator can accept ADC output with up to 65MSPS sampling rate and 14-bit resolution. The AFE5809 is available in a small 15mm x 9mm 135-pin BGA package.



AFE5809 functional diagram.

Ultrasound

Fully Integrated 8-Channel Analog Front Ends with CW

AFE5807, AFE5808A

NEW

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/afe5807** or **www.ti.com/sc/device/afe5808a**

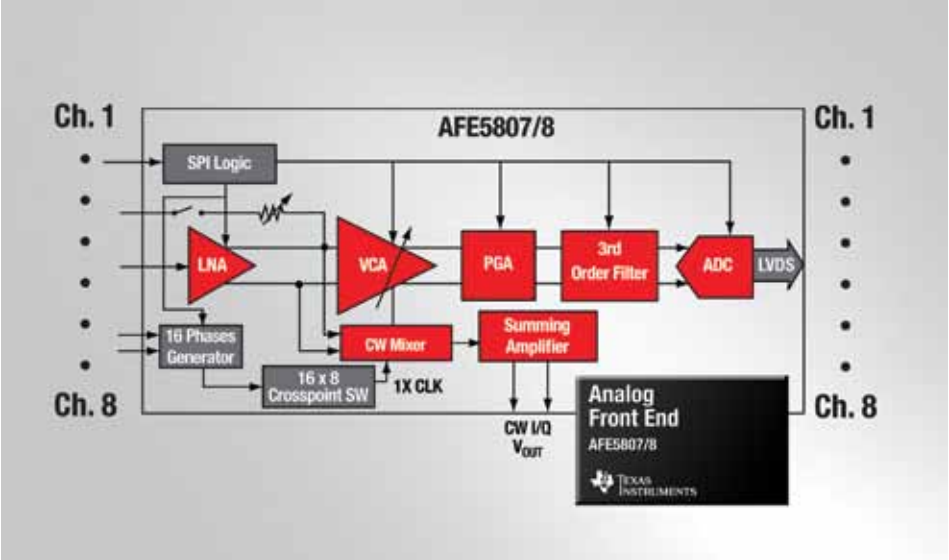
Key Features

- Integrated CW Doppler mixer and summing amplifier with a very low close-in phase noise better than –156dBc/Hz at 1KHz off a 2.5MHz carrier to ease design with CW beamforming
- AFE5807 is low-power, high sampling rate with 117mW/CH at 1.05nV/rtHz, 80MSPS
- AFE5808A is high-performance with low-noise optimization of 0.75nV/rtHz, at 158mW/CH 65MSPS and a 12/14-bit ADC with 77dBFS SNR

Applications

- Ultrasound
- Non-destructive testing
- Sonar
- Radar

The AFE5807 and AFE5808A consist of eight channels each, including a low-noise amplifier, a voltage controlled attenuator, a programmable gain amplifier, a third order filter, and a 14-bit, analog-to-digital converter with LVDS output. Most importantly, these products integrate the continuous wave Doppler mixer enabling ease of design for Spectral Doppler systems to measure blood flow velocity. The integrated CW mixer for CW beamforming has a very low close-in phase noise better than –156dBc/Hz at 1KHz off a 2.5MHz carrier. They are both available in a small 15mm x 9mm 135-pin BGA package.



AFE5807 and AFE5808A functional diagram.

Ultrasound

Fully Integrated 8-Channel Analog Front End

AFE5803

NEW

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/afe5803**

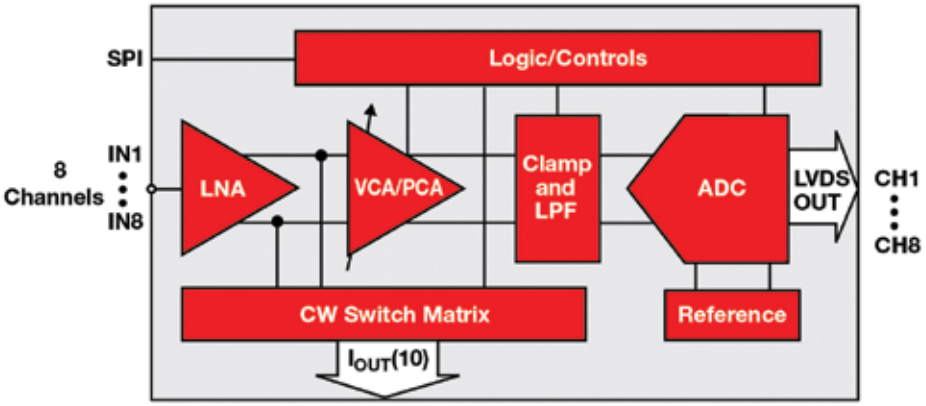
Key Features

- Integrated LNA, VCA, PGA, LPF, 14-bit ADC with LVDS output up to 65MSPS
- Low-noise optimization of 0.75nV/rtHz, 149mW/ch, 65MSPS and an ADC with 77dBFS SNR
- Total max gain: 54db and 0.25/0.5/1 V_{pp} linear input range
- Third order linear phase LPF with selectable bandwidth of 10, 15, 20, and 30MHz and 50, 100, 200 or 400Ω active termination
- Package: 135-pin 15mm x 9mm BGA

Applications

- Ultrasound
- Non-destructive testing
- Sonar
- Radar

The AFE5803 consists of eight channels, including a low-noise amplifier, a voltage controlled attenuator, a programmable gain amplifier, a third order filter, and a 14-bit, analog-to-digital converter with LVDS output. It has the best-in-class noise performance at 0.75nV/rtHz and is available in a small 15mm x 9mm 135-pin BGA package.



AFE5803 functional diagram.

Ultrasound

Octal, 12-/14-Bit, 80 MSPS ADC

ADS5292/ADS5294

NEW

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/ads5292** or **ads5294**

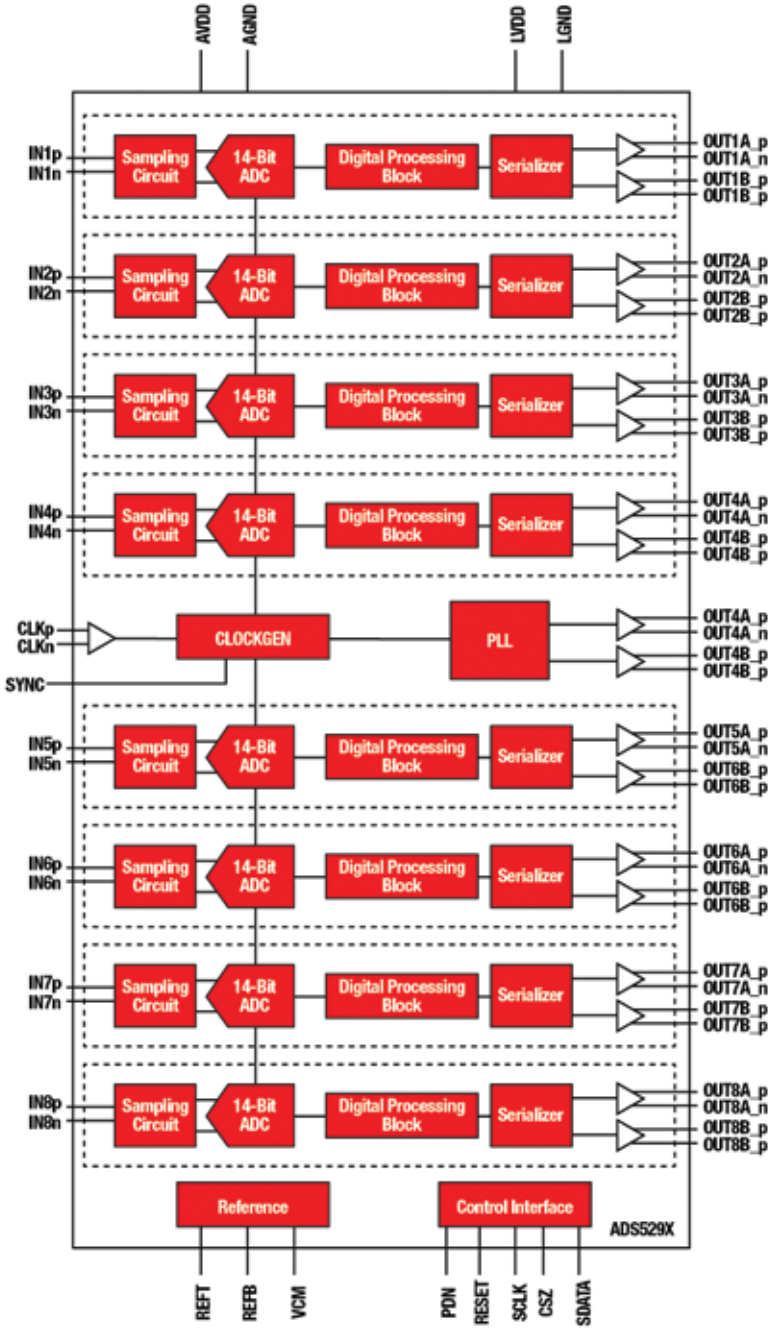
Key Features

- ADS5294 – 14-bit
  - 75.5dBFS SNR at 5MHz/80 MSPS
  - 78.2dBFS SNR at 5MHz and decimation filter
  - 84dBc SFDR at 5MHz/80MSPS
  - 77mW/ch at 80MSPS (2 LVDS wires/cH)
  - 58mW/ch at 50MSPS (1 LVDS wire/cH)
- ADS5292 – 12-bit
  - 70dBFS SNR at 5MHz/80MSPS
  - 71.5dBFS SNR at 5MHz and decimation filter
  - 85dBc SFDR at 5MHz/80MSPS
  - 54mW/ch at 65MSPS
  - 66mW/ch at 80MSPS (2 LVDS wires/ch)
- Digital processing block integrates several commonly used system functions such as two- or four-channel averaging and decimation by two, four or eight filters.
- Digital data can be output over one or two wires of LVDS pins per channel

Applications

- Ultrasound
- Non-destructive testing
- Radar
- Multi-channel data acquisition

The ADS5294 meets designers' needs for power-efficient, cost effective designs by delivering a best in class SNR of 75.5dBFS at 5MHz and a sampling frequency of up to 80MSPS. The ADS5292 offers low power consumption of 66mW/channel at 80MSPS. The ADS5292/4 allows engineers to design smaller, more compact systems than were previously possible with existing single-, dual-, or quad-channel devices.



ADS5292/4 functional diagram.

Ultrasound

Transmit Family

LM96530/50/70

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **lm96530**, **lm96550**, or **lm96570**)

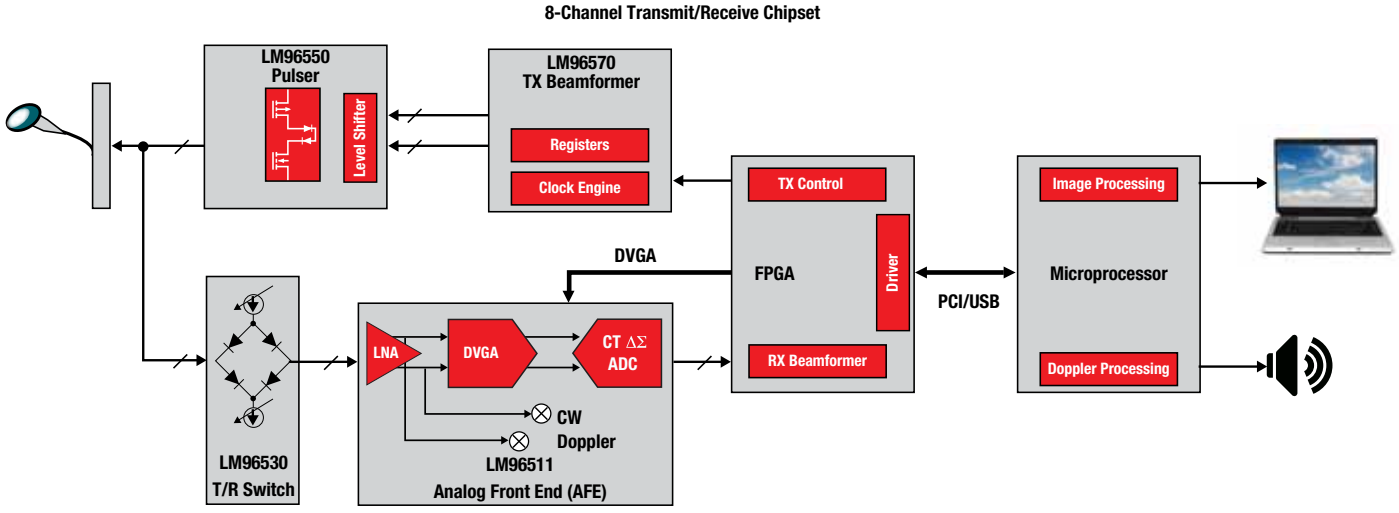
The LM965xx family offers a complete medical ultrasound transmit solution targeted for low power, portable systems. The family includes the T/R switch, the pulser, and the beamformer for pulse generators.

Key Features

- LM96530: Ultrasound transmit/ receive switch
  - 8-channel high-voltage receive side switches without charge-injection
  - Can be used for receive protection and/or receive multiplexing with SPI™ compatible bus control
  - Channel bandwidth supports 1MHz to 20MHz transducers
  - Input accepts pulses and continuous-wave signals within ±60V
- LM96550
  - 8-channel high-voltage CMOS pulse generator
  - Output pulses with ±50V and 2A peak current
  - Active damper with built-in blocking diodes
  - Built-in floating supply voltages for output stage
- LM96570
  - Full control over selecting beam directions and pulse patterns by programming individual channel parameters
  - Outputs interface seamlessly with positive and negative inputs on octal high-voltage pulser ICs
  - Beamformer timing provides: Delay resolution of 0.78ns

Applications

- Ultrasound
- Radar
- Sonar



Transmit system block diagram.

Ultrasound

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Analog Front Ends				
AFE5807	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 12-Bit, 80-MSPS ADC and CW	Low power solution with 117mW/ch at 1.05 nV/√Hz, 80MSPS. Low close-in phase noise better than –156dBc√Hz at 1KHz off a 2.5 MHz carrier.	Fully integrated AFE with CW mode to display blood flow velocity in Spectral Doppler ultrasound systems	AFE5808A
AFE5809	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 14-Bit, 65-MSPS ADC and CW with demodulatation	Low-noise optimization of 0.75nV/√Hz, 149mW/ch, 65MSPS and an ADC with 77dBFS SNR. Low close-in phase at –156dBc√Hz at 1KHz off a 2.5 MHz carrier.	Fully integrated AFE with CW mode to display blood flow velocity in Spectral Doppler ultrasound systems	AFE5808A
AFE5808A	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 14-Bit, 65-MSPS ADC and CW	Low-noise optimization of 0.75nV/√Hz, 158mW/ch, 65MSPS and an ADC with 77dBFS SNR. Low close-in phase at –156dBc√Hz at 1KHz off a 2.5 MHz carrier.	Fully integrated AFE with CW mode and digital demodulator to reduce overall system cost and power	AFE5807
AFE5803	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 14-Bit, 65-MSPS ADC	Low-noise optimization of 0.75nV/√Hz, 158mW/ch, 65MSPS and an ADC with 77dBFS SNR.	Best in class noise at 0.75nV/√HzHz	AFE5805
LM96511	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 12-Bit, 50-MSPS ADC and CW	110mW/channel low power, 0.9nV/√Hz low noise, 135-pin 15 x 9 BGA package	Enables portability, greater number of channels per system and maintains good image quality	AFE5805
AFE5801	8-Channel Integrated Analog VCA, PGA, LPF and 12-bit, 65 MSPS ADC	50mW/channel at 30MSPS, 58mW/channel at 50MSPS, 64-pin 9 x 9 QFN package	Low power enables handheld ultrasounds	AFE5851
AFE5804	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 12-bit, 50-MSPS ADC	101mW/channel low power, 1.23nV/√Hz low noise, 135-pin 15 x 9 BGA package	Enables portability, greater number of channels per system and maintains good image quality	AFE5805, VCA8500 with ADS5281
AFE5805	8-Channel Integrated Analog LNA, VCA, PGA, LPF and 12-bit, 50-MSPS ADC	122mW/channel low power, 0.85nV/√Hz low noise, 135-pin 15 x 9 BGA package	Enables portability, greater number of channels per system and maintains good image quality	AFE5804
AFE5851	16-Channel Integrated Analog VCA, PGA, LPF and 12-bit, 65-MSPS ADC	39mW/channel at 32.5MSPS, 64-pin 9 x 9 QFN package	High channel count and low power allows increased channel density in handheld ultrasounds	AFE5801
Amplifiers				
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPAx695	High-Speed Op Amp	G = +2 BW 1400MHz, G = +8 BW 450MHz, 4300V/µs SR	Ultra-wideband, current feedback	OPA2695 (dual)
OPAx832	Video Buffer Op Amp	G = +2 BW 80MHz, 3.9mA supply, 350V/µs SR	Low power, fixed gain	OPA2832 (dual)
OPA847	VFB Op Amp	3.9GHz GBW, 0.85nV/√Hz noise, 950V/µs SR	High DC accuracy, stable for gains ≥12V/V	
OPA211	Precision Op Amp	1.1nV/√Hz noise at 1kHz, ±2.25V to ±18V supply, 80MHz BW	Unity gain stable, RRO, wide supply range	OPA227
OPA369	Nanopower Zero-Crossover Op Amp	1.8V to 5.5V, 700nA I_Q, CMRR 114dB RRIO, 0.4µV/°C, V_{OS} drift	Zero-crossover input offers excellent CMRR over entire input range	OPA379, OPA349
LPV521	Nano Power Amplifier	1.6V, 345nA, RRIO, 120dB CMRR, 0.4µV/°C drift	Lowest power, high CMRR	LPV511, OPA369
OPA695	Ultra-Wideband, Current-Feedback Operational Amp	±4.2V output voltage swing, low disabled power of 0.5mW, ultra-high slew rate	Gives more than adequate 0.8ns rise time for a 2V output step for the highest speed video requirements	
OPA2695	Dual, Wideband, Current-Feedback Operational Amp	±4.2V output voltage swing, low quiescent current, low disable current	Optimized for high gain operation	
OPA2889	High-Speed Op Amp	460µA/channel quiescent current	Very low power	OPA2890
THS4131	High-Speed Op Amp	150MHz (–3dB) BW, 51V/µs SR, –100dB THD	Differential input/differential output	THS4120, THS4150
THS4304	High-Speed Op Amp	3GHz BW, 830V/µs SR, 2.4nV/√Hz noise, 7.5ns settling time (001%)	High bandwidth and fast settling time	
THS4509	High-Speed Op Amp	1900MHz BW, 6600V/µs SR, 2ns settling time (1%)	Low distortion, fully differential	THS4508, THS4511

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New products are listed in ***bold red****.*

Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers (continued)				
THS4524	Very Low Power Quad Channel Rail-to-Rail Output Fully Differential Amplifier	Fully differential, 1.14-mA/ch current consumption	Low power signal conditioning	THS4521
TPA2010D1	Analog-Input Class-D Amp	2.5W mono, fully differential, filter-free Class D, in WCSP	Loud audio, long battery life, small package size	TPA2031D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA4411	Audio Headphone Amp	Audio headphone amp		TPA6130A2
TPA6205A1	Class-AB Audio Amp	1.25W mono, fully differential, Class AB	Loud audio, low cost	TPA6204A1
TPA6211A1	Class-AB Audio Amp	3.1W mono, fully differential, Class AB	Loud audio	
VCA2615	Dual, Low-Noise LNA and VCA	Very low noise: 0.7nV/$\sqrt{Hz}$	For high-end systems requiring high dynamic range and flexibility	VCA2611
VCA2617	Dual, Low-Power VCA	Differential I/O VCA, low power: 52mW/ch	Low-power, low-noise VCA to follow an off-chip LNA	VCA2614
VCA8500	8-Channel Ultrasound Front End	Complete with LNA, VCA and LPF; low noise and power: 0.8nV/$\sqrt{Hz}$ and 65mW/ch	Best-in-class noise-power combination	AFE5805
VCA8613	8-Channel Ultrasound Front End	Complete with LNA, VCA and LPF; low power: 75mW/ch	Best-in-class power	VCA8500
VCA8617	8-Channel Ultrasound Front End	Complete with LNA, VCA and LPF; low noise of 1.0nV/$\sqrt{Hz}$	Best-in-class noise	VCA8500
Data Converters				
ADS5292	High-Speed ADC	8-Channel, 12-bit 80MSPS, 78.2dBFS SNR at 5MHz and decimation filter	Best in class SNR performance improves systems sensitivity	ADS5294
ADS5294	High-Speed ADC	8-Channel, 14-bit 80MSPS, 54mW/ch at 65MSPS	Enables high density applications to increase channel count without increasing power	ADS5292
ADS1610	Delta-Sigma ADC	16-bit, 10MSPS, parallel interface	SYNC pin for simultaneous sampling	
ADS1605	Delta-Sigma ADC	16-bit, 5MSPS (10MSPS in 2x mode), 88dB SNR, –99dB THD	Selectable on-chip reference	
ADS5121	High-Speed ADC	8-channel, 10-bit, 40MSPS, 1.8V analog/digital supply	Low power, individual channel power down	ADS5122
ADS5232	High-Speed ADC	Dual 12-bit, 65MSPS, 3.3V analog/digital supply	Internal or external reference	
ADS5240	High-Speed ADC	4-channel, 12-bit, 65MSPS, 3.3V analog/digital supply	Serialzed LVDS outputs, integrated frame and bit patterns	ADS5242
ADS5281	High-Speed ADC	8-channel, ultra-low-power, 12- and 10-bit, 50 to 65MSPS analog-to-digital converter	77mW per channel, serialized LVDS outputs, 1/F noise-suppression	ADS5282, ADS5287
ADS5282	High-Speed ADC	Ultra-low-power, 8-channel, 12-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281
ADS5287	High-Speed ADC	Ultra-low-power, 8-channel, 10-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281
ADS7809	AR ADC	16-bit, 100kHz sample rate, 86dN SINAD with 20kHz input, serial ouput	Output sync pulse for ease of use with standard DSP processors	
ADS8284	SAR ADC	18-bit, 1MSPS, 4 MUX inputs, 98.5dB (typ) SNR at 10kHz	Integrated op amp, ultra-high DC and AC performance	
ADS8380	SAR ADC	18-bit, 600kHz sample rate, ±2 LSB (typ), pseudo-differential input	Zero latency, serial interface with clock up to 40MHz	
ADS8422	SAR ADC	16-bit, 4MSPS, parallel w/reference, pseudo bipolar, fully differential input	Low power	
ADS8484	High-Speed SAR	18-bit, 125MSPS, 98dB (typ) SNR, –110dB (typ) THD	Excellent drift performance	
ADS8519	Bipolar ADC	±10V bipolar, 16-bit, 250kSPS, 10mW at 250kSPS (typ)	Flexible voltage digital interface supports 1.8V I/O	
DAC2900	High-Speed DAC	10-bit, 125MSPS dual DAC	Supports 3.3/5V	DAC2902, DAC2904
DAC7568	12-Bit Octal Channel, Ultra-Low Glitch, Voltage Output DAC With 2.5V, 2-ppm/°C Internal Reference	DSP-compatible 3-wire serial interface with power on reset and power down features	Useful for portable ultrasound data conversion	DAC8168, DAC8568

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*New products are listed in **bold red**.*

Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters (continued)				
DAC8168	14-Bit Octal Channel, Ultra-Low Glitch, Voltage Output DAC With 2.5V, 2ppm/°C Internal Reference	DSP compatible 3-wire serial interface with power on reset and power down features	Useful for portable ultrasound data conversion	DAC7568, DAC8568
DAC8560	V_{OUT} DAC	16-bit, 0.15nV-s glitch, ±10µs to 0.003% FSR settling time	Small package, low power	DAC8554, DAC8551, DAC8552
DAC8568	16-Bit Octal Channel, Ultra-Low Glitch, Voltage Output DAC With 2.5V, 2ppm/°C Internal Reference	DSP compatible 3-wire serial interface with power on reset and power down features	Useful for portable ultrasound data conversion	DAC7568, DAC8168
DAC8330	Precision DAC	16-bit, V_{OUT}, 1LSB INL	Very low power, serial interface	DAC8331, DAC8830
DACx311	8 to 16-Bit, Single Channel, Low Power, Ultra-Low Glitch DAC	±2 LSB, scalable output range, SPI interface with 1.8V to 5.5V logic	Very low noise and fast settling time	
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF02	Precision V_{REF}	0.2% (max) initial accuracy, 10ppm/°C (max) drift, 1.4mA (max)	Excellent line/load regulation, low noise	REF5050
REF30xx	Low-Power, Low-Drift Series Reference	50µA, 0.2% initial accuracy, 50ppm/°C max drift, ±25mA output, 1.25V, 2.048V, 2.5V, 3.0V , 3.3V, 4.096V		REF31xx, REF33xx, REF29xx
REF31xx	Voltage Reference	15ppm/°C (max) drift, 5mV low dropout, 115µA (max) I_Q, 0.2% (max) accuracy, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	No load capacitor required	REF32xx, REF33xx
REF32xx	Low Drift, Bandgap	0.2% (max) accuracy, 7ppm/°C (max) drift, 0.1mA (max) I_Q	Multiple output voltages, SOT23-6	
REF33xx	Very-Low-Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF5010	Low Noise, Very-Low-Drift, Precision Voltage Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 10V	Improves system accuracy	REF102
REF50xx	High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Processors				
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
TMS320C6452	DSP	900MHz, 1.4MB L2 cache, 2x SGMII/Gigabit EMAC	High-performance DSP with improved system cost	
TMS320C6455	DSP	1.2GHz, SRIO, 2MB RA	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6472	DSP	6x 700MHz C64x+ cores, 4.8MB RAM, SRIO, HPI	High-performance multiprocessor solution	
TMS320C6474	DSP	3x 1.2GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6654	Industry's Most Efficient Floating-Point DSPs	850MHz, C66x single core, 2MB L2, 2W	Fixed and floating point DSP, 13.5 GFlops, 27 GMACS	
TMS320C6655	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x single core, 2MB L2, 2.5W	Fixed and floating point DSP, 20 GFlops, 40 GMACS	
TMS320C6657	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x dual core, 2MB L2, 3.5W	Fixed and floating point DSP, 40 GFlops, 80 GMACS	
TMS320C6678	Industry's Highest Performance Floating-Point DSPs	1.0, 1.25 GHz, eight C66x cores, 8MB L2, 10W	High-performance fixed and floating point DSP, 160 GFlops, 320 GMACS	
TMS320C6745	DSP	1800MFLOPS, 256KB L2	Low cost floating point, combines C64x+ and C67x cores	TMS320C671x

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Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (continued)				
TMS320C6747	Industry's Lowest Power Floating-Point DSPs	32-/64-bit accuracy, 1.8V to 3.3V I/O supply, low power and rich connectivity peripherals	Uses three times less power than existing floating-point DSPs	
TMS320DM355	Highly Integrated, Programmable Platform for Low Cost Portable Digital Video Apps	ARM926 at 216/270MHz; MPEG4 HD (720p) and JPEG up to 50M pixels per second	High quality, low-power consumption at low price	TMS320DM365, TMS320DM368
TMS320DM6446	Highly Integrated Video SoC	Robust operating systems support, rich user interfaces, high processing performance, and long battery life	High quality, low-power consumption at low price	TMS320DM6443, TMS320DM6441
TMS320F2802x/3x Piccolo™	32-Bit Microcontroller	Up to 60MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F283x Delfino™	32-Bit Floating-Point Microcontroller	Up to 300MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
Hercules RM48x	Safety Microcontroller	Up to 220MHz dual lockstep ARM® Cortex-R4 CPUs with floating point, up to 3MB Flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
Interface				
SN65LVDS387	16-Channel LVDS Driver	630Mbps	High-density LVDS driver	SN65LVDS386
SN65LVDS93A	24-Bit RGB LVDS Serdes	10MHz-135MHz, BGA and TSSOP; supports 1.8V to 3.3V TTL i/p	Wide frequency range, saves space, no level shifter for 1.8V powered uP	SN75LVDS83B
SN65MLVD047	4-Channel M-LVDS Driver	Higher differential swing	Industry standard	SN65LVDS348
Clocking				
CDCE62005	Clock Generator	RMS jitter <1ps, recommended clocking solution for AFE580x and ADS528x/527x	Integrated VCO saves system cost	CDCE72010, CDCM7005
CDCE(L)949	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE(L)937, CDCE(L)925
CDCE906	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE706
Pulsers and Switchers				
TX810	8-Channel Integrated T/R Switch	Eight bias current settings; eight power/performance combinations; accepts $200V_{PP}$ input signals	Compact T/R switch; flexible programmability; easy power-up/down control; fast wake-up time; dual supply operation; optimized insertion loss	LM96530
TX517	2-Channel High-Voltage Pulse Generator	Output pulses with ±90V with Xformer and 2A peak current	Integrated transmitter for multi-level waveforms	
LM96530	8-Channel Integrated T/R Switch	Input accepts pulses and continuous-wave signals within ±60V	Can be used for receive protection and/or receive multiplexing with SPI™ compatible bus control	LM96550, LM96570
LM96550	8-Channel High-Voltage Pulse Generator	Output pulses with ±50V and 2A peak current	Integrated solution with active damping for low noise operation	LM96530, LM96570
LM96570	Configurable Transmit Beamformer	Full control over selecting beam directions and pulse patterns by programming individual channel parameters	Outputs interface seamlessly with positive and negative inputs on octal high-voltage pulser ICs	LM96530, LM96550
Temperature Sensor				
TMP441	±Temperature sensor with automatic beta compensation, series-R and n-Factor in a 8-pin SOT23	±1°C remote diode sensor with ±1°C local temp sensor	Recommended for FPGA temp monitoring in ultrasound	TMP421

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*New products are listed in **bold red**.*

Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, Broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, Broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91, CC2530ZNP
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	
Toolkits				
STK-MED	A collection of several standard ultrasound algorithms optimized for TI's C64x+ DSP architecture	Standard APIs; tested, benchmarked and documented library modules	Shortens customer development time by providing highly opttimized C64x+ DSP source code of common ultrasound processing blocks	
DLP® LightCrafter™	A compact, versatile EVM for integrating light into medical applications	608x684 micromirror array, 7.6µm micromirror pitch, pattern rates up to 4000Hz, video display up to WVGA resolution	Has multiple industry standard interfaces including USB, mini-HDMI, and I^2C	

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CT Scanners

Computed Tomography

Computed tomography (CT) is a medical imaging technique that produces three-dimensional images of internal human body parts from a large series of two-dimensional X-ray images (called profiles) taken in a single-axis rotating structure called a gantry. When compared to a conventional X-ray radiograph, which is an image of many planes superimposed on each other, a CT image exhibits significantly improved contrast.

With the advent of diagnostic imaging systems like CT, where complex and intensive image processing is required, semiconductors play a very important role in developing systems with increased density, flexibility and high performance.

X-ray slice data is generated using an X-ray source that rotates around the object, with X-ray detectors positioned on the opposite side of the circle from the X-ray source. Many data scans are taken progressively as the object is gradually passed through the gantry. The newer helical or spiral CT machines that use faster computer systems and optimized software can continuously process the cross-section images while the object passes through the gantry at a constant speed.

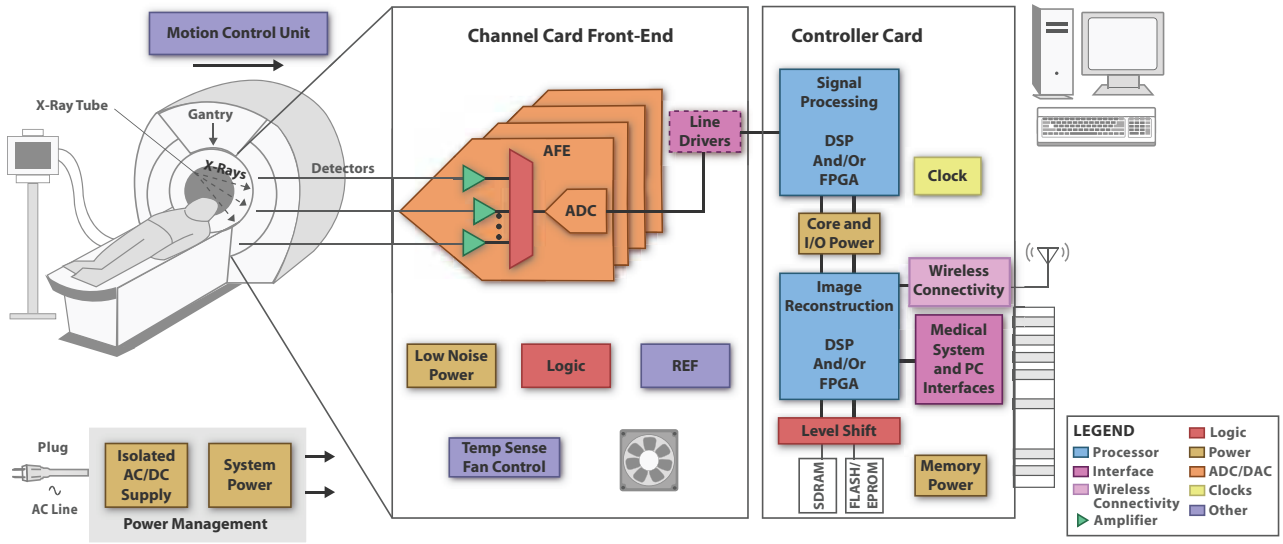
The detector system consists of a number of channel cards that have scintillator-photodiode solid state detectors. The X-rays interact with the scintillator and produce visible light, which is in turn converted into a current by the photodiode. The depth information along the direction of the X-ray beam that is lost in radiography is recovered by viewing the slide from many different directions.

The channel card has a front-end system where charge on the detectors are integrated, gained by amplifiers and converted to digital values by ADCs. The digital data from all channel cards is transferred by high-speed link to the controller card and onto the image conditioning cards. The image conditioning card is connected to the host computer where the CT images can be viewed. Here, the digital data are combined by the mathematical procedure known as tomographic reconstruction. Power supplies, clocks and clock distribution circuits, reference and reference buffers, logic, and interface products are some of the key blocks in the channel card subsystem.

Control cards can include DSPs and FPGAs, power supplies, clocks and clock distribution circuitry and interface blocks. DSPs can be used to provide accurate control of the gantry rotation, the movement of the table (up/down and in/out), tilting of the gantry for angled images, and other functions such as turning the X-ray beam on and off. Another important DSP control functionality is ECG gating used to reduce motion artifacts caused by heart movement. Here, the data acquisition is carefully synchronized with the heartbeat.

Product portfolio for CT scanners

- The DDC family are single-chip solutions for directly digitizing low-level currents from photodiode arrays in CT scanners.
- DSPs with TI's VelociTI™ VLIW architecture can provide accurate control of the gantry rotation, the movement of the table, the tilting of the gantry for angle images, and other real-time control and processing functions.
- Voltage supervisors, DC/DC converters, non-isolated power modules and low-dropout linear regulators to meet sequencing requirements.



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

CT scanner system block diagram.

CT Scanners

Dual, Current-Input, 20-Bit ADC

DDC264

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/ddc264**

Key Features

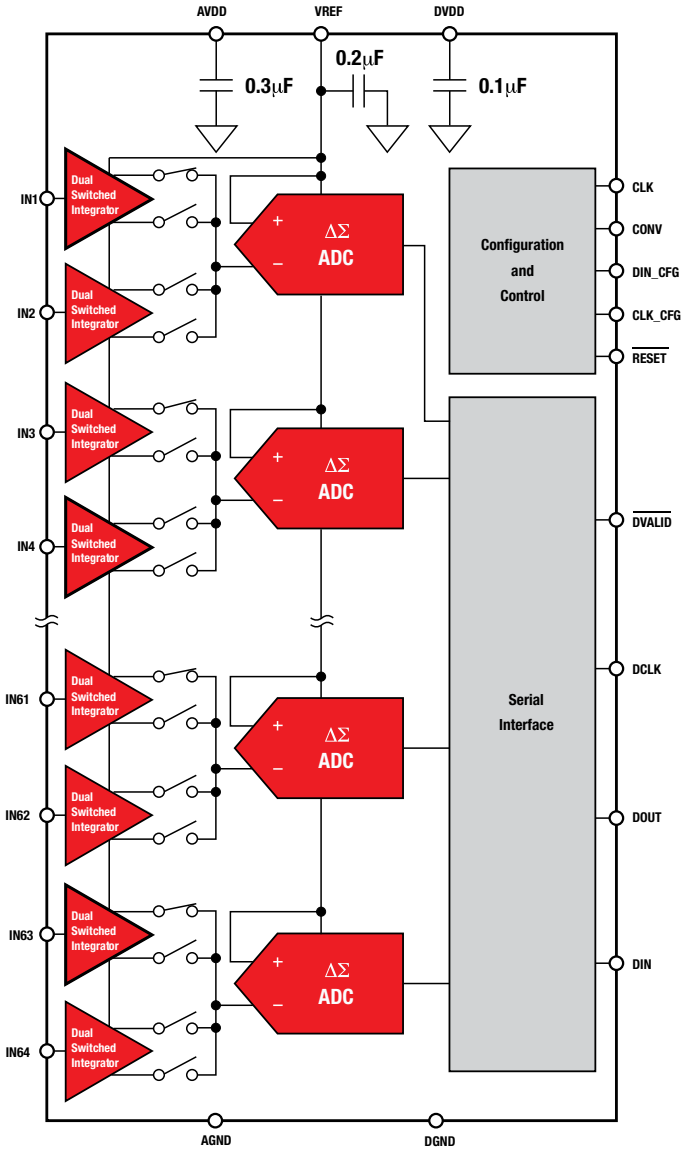
- Single-chip solution to directly measure 64 low-level currents
- Proven high-precision, true integrating architecture with 100% charge collection
- Easy upgrade for existing DDC family applications
- Very low power: 3mW/channel
- Extremely linear:
  INL = ±0.025% of reading ±1.0ppm of FSR
- Low noise: 6.3ppm of FSR
- Adjustable full-scale range

Applications

- CT scanners
- X-ray systems
- Photodiode sensor arrays

The DDC264 is a 20-bit, 64-channel, current-input analog-to-digital (A/D) converter. It combines both current-to-voltage and A/D conversion so that 64 separate low-level current output devices, such as photodiodes, can be directly connected to its inputs and digitized.

For each of the 64 inputs, the DDC264 uses the proven dual switched integrator front-end. This configuration allows for continuous current integration: while one integrator is being digitized by the onboard A/D converter, the other is integrating the input current. This architecture provides both a very stable offset and a loss-less collection of the input current. Adjustable integration times range from 16µs to 1s, allowing currents from fAs to µAs to be continuously measured with outstanding precision.



DDC264 functional diagram.

CT Scanners

Dual, Current-Input, 20-Bit ADC

DDC232

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/ddc232**

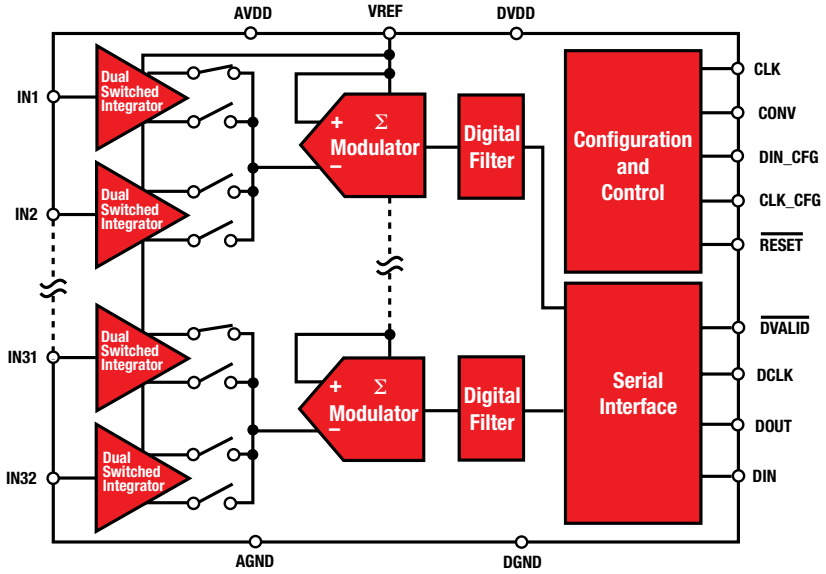
Key Features

- Complete solution for measuring 32 photodiodes with 20-bit resolution
- Continuous charge collection
- Adjustable integration time: 160µs to more than 1s
- Programmable full scale: 12.5pC up to 350pC
- Low noise: 5ppm, rms
- Integral nonlinearity: ±0.025% reading ±1ppm FSR
- Single supply with 7mW/channel power dissipation
- Serial digital interface with daisy chaining support
- Packaging: 8mm x 8mm BGA

Applications

- CT scanners
- X-ray systems
- Photodiode sensor arrays

The DDC products are single-chip solutions for directly digitizing low-level currents from photodiode arrays in CT scanners. The dual-integrator front-end provides continuous charge collection. While one integrator is collecting the photodiode current, the other is being measured by the onboard 20-bit ADC. Integration time is user-adjustable, and the output data is retrieved over a serial interface that can be daisy chained to minimize digital interconnects in high-channel-count systems.



DDC232 functional diagram.

CT Scanners

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifier				
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA2211	Lowest Power, 1.1nV/$\sqrt{Hz}$ Noise, Precision Operational Amplifier in DFN-8 (3 x 3mm) and SOIC-8	Extremely low voltage and low current noise, high speed and wide output swing	Allows 16-bit accuracy throughout 10V output swings	OPA627, OPA2111
OPA380	Transimpedance Amp	90MHz GBW, over 1MHz transimpedance BW, 25µV offset (max), 0.1µV/°C drift (max)	Precision, dynamic range 4 to 5 decades, excellent long term stability	OPA350, OPA335
OPA827	Precision JFET Op Amp	4nV/$\sqrt{Hz}$ noise at 1kHz, ±4V to ±18V supply, 15pA (typ) input bias current, 22MHz BW	High precision, low noise, low input bias, wide supply range	OPA177, OPA627,
Data Converters				
ADS8284	SAR ADC	18-bit, 1MSPS, 4 MUX inputs, 98.5dB (typ) SNR at 10kHz	Integrated op amp, ultra-high DC and AC performance	
ADS8317	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Excellent linearity, micropower, high speed	ADS8422
ADS8326	SAR ADC, Serial	16-bit, 250kSPS, 2.7V to 5.5V, pseudo-bipolar, diff inputs	Low noise, low power, high speed	ADS8325
ADS8482	SAR ADC	18-bit, 1MSPS, 2.25mW power, 99dB SNR, ±2.5 LSB (max) INL	Pseudo bipolar, internal or external reference	ADS8472, ADS8484
ADS8484	High-Speed SAR	18-bit, 125MSPS, 98dB (typ) SNR, –110dB (typ) THD	Excellent drift performance	
DDC112	2 Channels	50 to 100pC full-scale	Up to 3kSPS data rate, 40mW/Ch	SOIC-28 or TQFP-32
DDC114	4 Channels	12.5 to 350pC full-scale	Up to 3.1kSPS data rate, 13.5mW/Ch	QFN-48
DDC118	8 Channels	12.5 to 350pC full-scale	Up to 3kSPS data rate, 40mW/Ch	QFN-48
DDC232	32 Channels	12.5 to 350pC full-scale	Up to 6kSPS data rate, 7mW/Ch	BGA-64
DDC264	64 Channels	12.5 to 150pC full-scale	Up to 6kSPS data rate, 5.5mW/Ch	BGA-100
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF02	Precision V_{REF}	0.2% (max) initial accuracy, 10ppm/°C (max) drift, 1.4mA (max)	Excellent line/load regulation, low noise	REF5050
REF102	10V, Ultra Precision	0.05% (max) initial accuracy, 2.5ppm/°C (max) drift, 1.4mA (max)	Excellent stability and line/load regulation	REF5010
REF31xx	Voltage Reference	15ppm/°C (max) drift, 5mV low dropout, 115µA (max) I_Q, 0.2% (max) accuracy, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	No load capacitor required	REF3130, REF3120
REF32xx	Low Drift, Bandgap	0.2% (max) accuracy, 7ppm/°C (max) drift, 0.1mA (max) I_Q, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Multiple output voltages, SOT23-6	
REF33xx	Very Low Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF5010	Low Noise. Very Low Drift, Precision Voltage Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 10V	Improves system accuracy	REF102
REF50xx	High-Precision, Very Low Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V , 5.0V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

CT Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
TMS320C-6455BZTZ	DSP	1.2GHz, SRIO, 2MB RAM	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320F2808	Digital Signal Controller	100MIPS, 8KB ROM, 36KB RAM, 128KB flash, 12-bit ADC	I^2C, 4 SPI, 2 SCI, 2 CAN	
TMS320F2812	Digital Signal Controller	150MIPS, 8KB ROM, 36KB RAM, 256KB flash, 12-bit ADC	McBSP, 1 SPI, 2 SCI, 1 CAN	
TMS320F28015	Digital Signal Controller	60MIPS, 8KB ROM, 12KB RAM, 32KB flash, 12-bit ADC	I^2C, 1 SPI, 1 SCI	
TMS320F2802x/3x Piccolo™	32-Bit Microcontroller	Up to 60MHz C28x™ core with optional control law accelerator. Up to 128KB Flash, high resolution (150ps) PWMs, 4.6MSPS ADC, CAN/LIN, QEP.	With dedicated, high precision peripherals, Piccolo microcontrollers are the ultimate combination of performance, integration, size, and low cost. Ideal for precision sensing and control applications.	TMS320F283x Delfino, TMS320F280x
TMS320F283x Delfino™	32-Bit Floating-Point Microcontroller	Up to 300MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
Hercules RM48x	32-Bit Floating-Point Safety Microcontroller	Up to 220MHz Dual Lockstep ARM® Cortex-R4 CPUs with Floating Point, up to 3MB Flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
TMS320C6474	DSP	3x 1GHz C64x+™ DSP cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6655	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x single core, 2MB L2, 2.5W	Fixed and floating point DSP, 20 GFlops, 40 GMACS	
TMS320C6657	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x dual core, 2MB L2, 3.5W	Fixed and floating point DSP, 40 GFlops, 80 GMACS	
TMS320C6678	Industry's Highest Performance Floating-Point DSPs	1.0, 1.25 GHz, eight C66x cores, 8MB L2, 10W	High-performance fixed and floating point DSP, 160 GFlops, 320 GMACS	
Interface				
XIO1100	x1 PCIe PHY	Interface FPGA to PCIe fabric between channels	PCIe 1.1 compliant, flexible MAC interface	
TLK1221	Gigabit Ethernet Serdes	Power 250mW	Smallest package	TLK2208B
SN65LVCP40	Dual 1:2 Mux/ Buffer	Input EQ, output pre-emp	Improves signal range	
SN65LVDS93A	24-bit RGB LVDS Serdes	10MHz-135MHz, BGA and TSSOP; supports 1.8V to 3.3V TTL i/p	Wide frequency range, saves space, no level shifter for 1.8V powered uP	SN75LVDS83B
Clocking				
CDCLVP12xx/ 21xx	1:2/4/8/12/16 or Dual 1:2/4/6/8 Universal-to-LVPECL Clock Buffers	Very low additive jitter <100ps RMS; 2.5V / 3.3V operation	Improved clock signal quality by 10x; saves additional interface logic / external components	CDCLVP111, CDCLVP215
Analog Multiplexers				
TS3A5017	Dual SP4T 3.3-V/2.5-V Analog Multiplexer/ Demultiplexer	Low total harmonic distortion	Excellent signal integrity in both digital and analog applications	
TS3A5018	Quad SPDT 3.3V/2.5V Analog Switch	Low on state resistance and matching (R_{ON} = 10)	Minimizes signal loss and ensures less variance	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI)
Magnetic resonance imaging (MRI) is a non-invasive diagnostic technology that produces physiologic images of the human body. Powerful magnets create a field that forces hydrogen atoms in the body into a particular alignment. Radio frequency (RF) energy distributed throughout the body is interrupted by body tissue. The disruptions correspond to varying return signals which, when processed, create the image.

Accurate signal processing is key to obtaining high-quality images. A key system consideration for the receive channel is high SNR. The return signals have narrow bandwidths, with an IF location dependent on the main magnet's strength. Some systems use high-speed pipeline ADCs with wide-band amplifiers to sample the IF, leaving large headroom for post-processing gain by a digital down converter or FPGA. Other systems mix the IF to baseband where lower speed, higher resolution SAR and delta-sigma ADCs can be used.

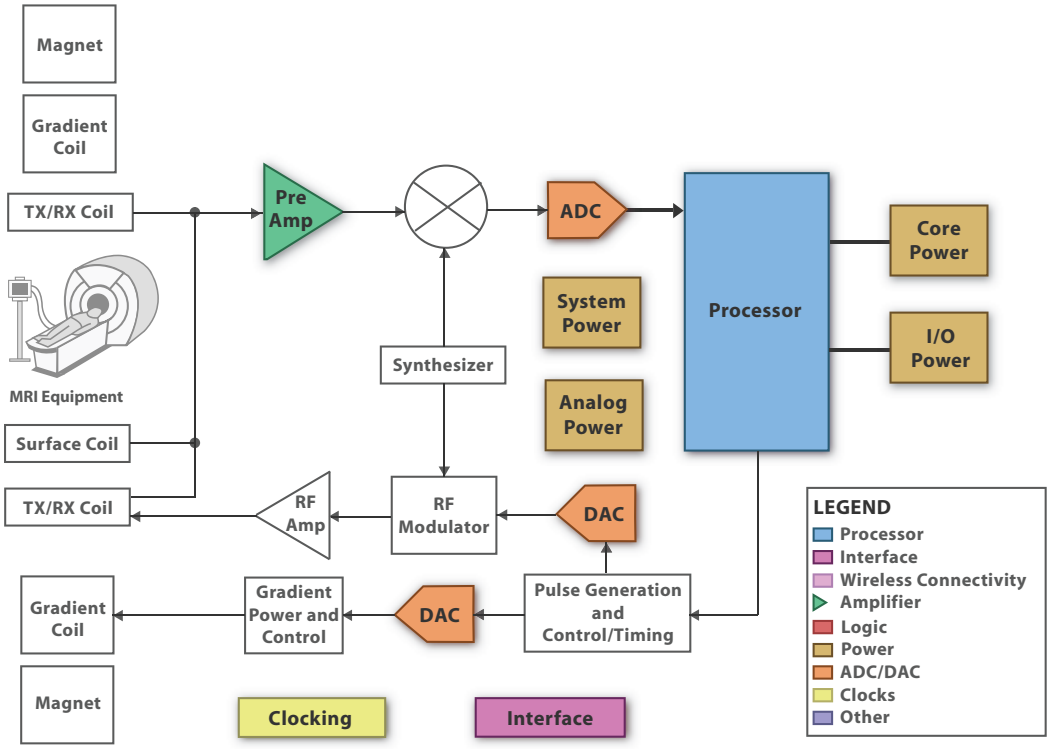
High-resolution, high-speed DACs are needed to control the magnetic and RF energy in the MRI. High resolution is required to accurately define the area of the patient to be scanned and high speed is needed to match the high IFs generated by the main magnet.

DSPs can be used to provide gradient processor control for properly controlling MRI system magnets. DSPs are also useful for implementing signal processing functionalities in MRI devices. MRI reconstruction is based mostly on 2-D Fourier transformation. In addition, functionalities like auto- and cross-correlation, curve fitting, combining sub-images and motion stabilization are required to pre- and post-process the image to reduce various artifacts.

Analog ICs and embedded processors are playing a key role in improving the delivery speed and crisp detail of magnetic resonance images, leading to more accurate diagnoses and effective treatments. Accurate signal processing is key to high-quality MRI images.

Product portfolio for MRIs

- Some systems use high-speed pipeline ADCs with wideband amplifiers to sample the intermediate frequency (IF) generated by the main magnet.
- Other systems mix the IF to baseband, allowing for the use of lower speed, higher resolution successive approximation registers (SARs) and delta-sigma ADCs.
- High-resolution DACs can control the magnetic and RF energy in an MRI.
- DSPs like the TMS320C6452 can provide gradient processor control for properly controlling the magnets and preprocess the signal before it reaches the image reconstruction engine.
- Other products for MRI systems and equipment manufacturers include operational amplifiers, clocking distribution, interface and power management devices.



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Magnetic resonance imaging (MRI) system block diagram.

Magnetic Resonance Imaging (MRI)

Quad, 16-Bit, 100 MSPS ADC

ADS5263

NEW

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/ads5263**

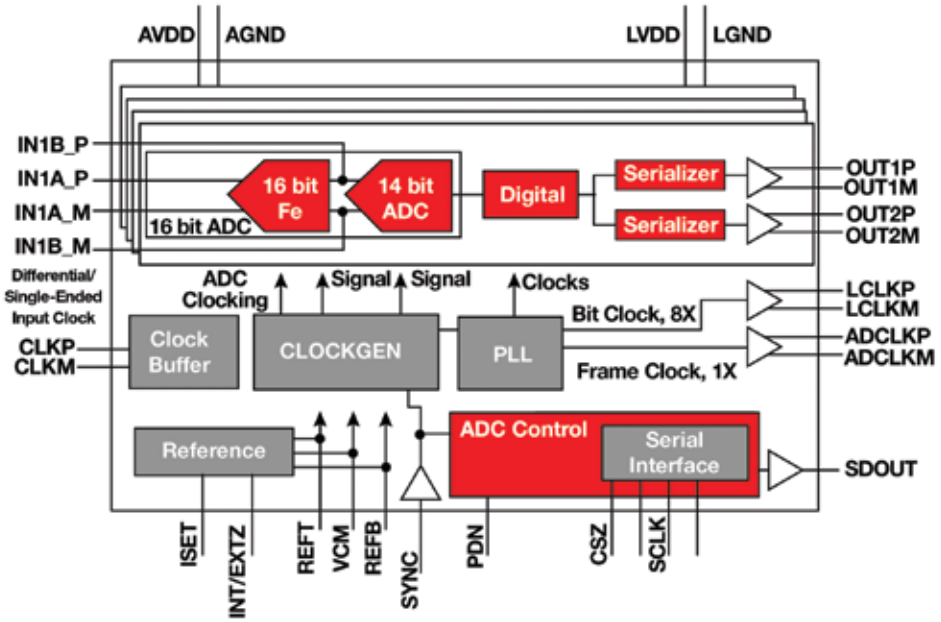
Key Features

- 16-bit resolution with up to 100MSPS sampling frequency for highest performance
- SNR of 84.6dBFS at 10MHz for best image quality
- Low-power consumption of 380mW/channel for compact medical imaging systems
- 14-bit and 16-bit resolution modes to switch between low-power and high-speed, high-resolution operation
- Quad-channel in 9mm x 9mm QFN package brings 50% board space savings
- Non-magnetic package option allows for operation in a strong magnetic field such as in magnetic resonance imaging (MRI) and other high-resolution applications

Applications

- MRI
- Radar

The ADS5263 delivers a very high SNR of 84.6dBFS, with 10MHz input and a sampling frequency up to 100MSPS. Together with up to $4V_{pp}$ full-scale input, this enables a very strong signal and a high-range of signal variations for best image clarity and contrast. The quad-channel architecture, the low power consumption of 380mW/channel and the small footprint of the ADS5263 allows system designers to design smaller, more compact systems than was previously possible with existing single or dual channel solutions. A non-magnetic package option allows for operation in a strong magnetic field, such as in MRI machines.



ADS5263 functional diagram.

Magnetic Resonance Imaging (MRI)

NEW

Non-Magnetic Packages

For more information visit **www.ti.com/nonmagnetic**

Key Features

- Removal of every magnetic component from silicon and package
- Allows for operation without distortion in strong magnetic fields
- Cost-effective design allows designers to remove shield previously needed

Applications

- MRI

TI's non-magnetic packages remove every magnetic component (such as nickel and iron) from its silicon and package. Non-magnetic package options allow for operation without distortion in strong magnetic fields. Non-magnetic packages allow engineers to design more compact, cost-effective designs, where previously designers had to design in shields around the components to protect them from the magnetic fields..

Non-magnetic components.

Non-Magnetic Components	
ADS5263IRGCT-NM	Analog-digital converter – 16-bit/14-bit ADC, 100 MSPS, BW>130MHz: QFN 9mm x 9mm 64-leads
TPS715A01DRBT-NM	80mA adjustable LDO 1.2V/15V: QFN 3mm x 3mm (DRB 8 leads)
TLC7701IDRBT-NM	Power management micro power supply voltage supervisor, QFN 3mm x 3mm (DRB 8 leads)
TS5A22362DRCT-NM	Analog switch – 0.65Ω dual SPDT analog switch, QFN 3mm x 3 mm (DRC 10 leads)
TPD2E001DRST-NM	15KV ESD diodes – 5V double I/O low cap IEC ESD diodes, QFN 3mm x 3mm (DRS 6-leads)
MSP430F2618TPMT-NM	Microcontroller – ultra-low-power microcontrollers, 64-LQFP 12mm x 12mm PM (S-PQFP-G64)

*New products are listed in **bold red**.*

Magnetic Resonance Imaging (MRI)

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
ADS5263-NM	Quad, 14-/16-Bit, 100MSPS, 84.6dBFS ADC	Non-magnetic package	Operation without shielding in strong magnetic field	
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
TPS715A01-NM	80mA Adjustable LDO 1.2V/15V	Non-magnetic package	Operation without shielding in strong magnetic field	
TLC7701-NM	Micro Power Supply Voltage Supervisor	Non-magnetic package	Operation without shielding in strong magnetic field	
TS5A22362-NM	0.65Ω Dual SPDT Analog Switch	Non-magnetic package	Operation without shielding in strong magnetic field	
TPD2E001-NM	5V Double I/O Low Cap IEC ESD Diode	Non-magnetic package	Operation without shielding in strong magnetic field	
MSP430F2618-NM	Ultra-Low-Power Microcontrollers	Non-magnetic package	Operation without shielding in strong magnetic field	
OPA861	Transconductance Amp	80MHz, open loop, G = +5BW, 900V/µs SR	95mA/V high transconductance, 5.4mA I_Q	
PGA870	Fully Differential PGA	650MHz BW, gain range: –11.5dB to +20dB, OIP3 +47dBm at 100MHz	Optimized for low distortion, accomodates varying signal levels	
THS4503	High-Speed Op Amp	370MHz BW, 3700V/µs SR, 5V, ±5V, 12V and 15V supply	Low distortion, fully differential	THS4504, THS4141
THS9000	Cascadeable Amp	50MHz to 400MHz, 50Ω input/output impedance	High dynamic range, single supply	
Data Converters				
ADS5263	High Speed ADC	Quad, 16bit/14bit, 100MSPS, 84.6dBFS	High performance for best image quality	
ADS1605	16-bit, 10-MSPS Delta-Sigma ADC	10 to 5MSPS, parallel interface with direct connection to TMS320 DSPs	Provides key system-level design advantages with respect to anti-aliasing filtering and clock jitter	ADS1610
ADS1610	Delta-Sigma ADC	16-bit, 10MSPS, parallel interface	SYNC pin for simultaneous sampling	ADS1605
ADS5281	High-Speed ADC	8-channel, ultra-low-power, 12- and 10-bit, 50 to 65MSPS analog-to-digital converter	77mW per channel, serialized LVDS outputs, 1/F noise-suppression	ADS5282, ADS5287
ADS5282/87	High-Speed ADC	Ultra-low-power, 8-channel, 12-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281, ADS5287
ADS5423	High-Speed ADC	14-bit, 80MSPS, 74dBc at 80MSPS and 50MHz IF SNR	3.3V CMOS-compatible outputs, 2s-complement output format	ADS5424, ADS5433
ADS5545	High-Speed ADC	14-bit, 170MSPS, DDR LVDS/CMOS outputs	Programmable output clock position to ease data capture	ADS5546, ADS5547
ADS5547	High-Speed ADC	14-bit, 210MSPS, user-selectable DDR LVDS or CMOS parallel outputs	High performance	ADS5545, ADS5546
ADS5562	High-Speed ADC	Low-power, 16-bit ADC with up to 84dBFS SNR	High SNR, 1/f noise suppression with low power and small package ease data capture	ADS5560
ADS61xx/61Bxx	High-Speed ADC	11- /12- /14-bits, 65 to 250MSPS, 3.3V, 260 to 780mW per channel	High performance	ADS62xx, ADS62Pxx, ADS64xx
ADS62xx/62Pxx	High-Speed ADC	11- /12- /14-bits, 65 to 250MSPS, 3.3V, 260 to 780mW per channel	High performance	ADS61xx, ADS61Bxx, ADS64xx
ADS64xx	High-Speed ADC	11- /12- /14-bits, 65 to 250MSPS, 3.3V, 260 to 780mW per channel	High performance	ADS61xx, ADS61Bxx, ADS62xx, ADS62Pxx
ADS6425	High-Speed ADC	4-channel, 12-bit, 125MSPS, serial LVDS interface, 1.65W total power	High performance, multiple input option	
DAC904	High-Speed DAC	14-bit, 165MSPS DAC	Low-power DAC	
DAC5672	High-Speed DAC	14-bit, 275MSPS dual DAC	High sample rate with low power	DAC5662, DAC5652
DAC5681Z	High-Speed DAC	16-bit, 1GSPS 2x-4x interpolating DAC	High sample rate allows direct launch to low RF	DAC5681, DAC5682Z
DAC5687	High-Speed DAC	16-bit, 500MSPS interpolating with NCO	Digital integration and superior AC performance for flexible application and high-quality transmission	DAC5686
DAC7725	V_{OUT} DAC	Quad, 12-bit, 250mW (max) power, 10µs to 0.012% settling time	Double-buffered data inputs	DAC7724, DAC902, DAC900

*To view more system block diagram compatible products, visit **www.ti.com/healthtech***

*New products are listed in **bold red**.*

Magnetic Resonance Imaging (MRI)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF02	Precision V_{REF}	0.2% (max) initial accuracy, 10ppm/°C (max) drift, 1.4mA (max)	Excellent line/load regulation, low noise	REF5050
REF102	10 V, Ultra Precision	0.05% (max) initial accuracy, 2.5ppm/°C (max) drift, 1.4mA (max)	Excellent stability and line/load regulation	REF5010
REF31xx	Voltage Reference	15ppm/°C (max) drift, 5mV low dropout, 115µA (max) I_Q, 0.2% (max) accuracy, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	No load capacitor required	REF31xx, REF32xx, REF33xx
REF32xx	Low Drift, Bandgap	0.2% (max) accuracy, 7ppm/°C (max) drift, 0.1mA (max) I_Q, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Multiple output voltages, SOT23-6	
REF33xx	Very Low Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF5010	Low Noise, Very Low Drift, Precision Voltage Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 10V	Improves system accuracy	REF102
REF50xx	High-Precision, Very Low Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Processors				
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
TMS320C6452/55	DSP	900MHz, 1.4MB L2 cache, 2 x SGMII/Gigabit EMAC	High-performance DSP with improved system cost	TMS320C6414, TMS320C6455, TMS320C6454, TMS320C6747
TMS320C-6455BZTZ	DSP	1.2GHz, SRIO, 2MB RAM	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6655	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x single core, 2MB L2, 2.5W	Fixed and floating point DSP, 20 GFlops, 40 GMACS	
TMS320C6657	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x dual core, 2MB L2, 3.5W	Fixed and floating point DSP, 40 GFlops, 80 GMACS	
TMS320C6678	Industry's Highest Performance Floating-Point DSPs	1.0, 1.25 GHz, eight C66x cores, 8MB L2, 10W	High-performance fixed and floating point DSP, 160 GFlops, 320 GMACS	
TMS320F2808	32-Bit MCU	100MIPS, 8KB ROM, 36KB RAM, 128KB flash, 12-bit ADC	I^2C, 4 SPI, 2 SCI, 2 CAN	
TMS320F28015	32-Bit MCU	60MIPS, 8KB ROM, 12KB RAM, 32KB flash, 12-bit ADC	I^2C, 1 SPI, 1 SCI	
TMS320F28234	32-Bit MCU	150MIPS, 8KB ROM, 68KB RAM, 256KB flash, 12-bit ADC	McBSP, 1 SPI, 2 SCI, 2 CAN	
TMS320F283x Delfino™	32-Bit Floating-point Microcontroller	Up to 300MHz C28x™ core. Up to 512KB Flash, high resolution (150ps) PWMs, 12MSPS ADC, CAN/LIN, QEP, external memory bus, DMA.	Delfino brings floating point and unparalleled performance to MCUs. Native floating point brings increased performance and quicker development. Ideal for precision sensing and control applications.	TMS320F2802x/3x Piccolo, TMS320F280x
Hercules RM48x	32-Bit Floating-Point Safety Microcontroller	Up to 220MHz Dual Lockstep ARM® Cortex-R4 CPUs with Floating Point, up to 3MB Flash w/ECC, up to 256KB RAM w/ECC, USB host/device, Ethernet, CAN, SPI, UART, 12-bit ADC, NHET co-processor for PWM generation and input capture	Simplified development for safety critical applications, large integrated flash memory, rich peripherial set	
TMS320C6474	DSP	3 x 1GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
Interface				
SN65MLVD128	1:8 Fanout Buffer	200Mbps	Standardized M-LVDS	SN65MLVD2
SN65LVDS93A	24-Bit RGB LVDS Serdes	10MHz-135MHz, BGA and TSSOP; supports 1.8V to 3.3V TTL i/p	Wide frequency range, save space, no level shifter for 1.8V powered uP	SN75LVDS83B

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Magnetic Resonance Imaging (MRI)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Clocking				
CDCE62005	Clock Generator	rms jitter <1ps, recommended clocking solution for AFE580x and ADS528x/527x	Integrated VCO saves system cost	CDCE72010, CDCM7005
CDCE(L)949	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE(L)937, CDCE(L)925, CDCE(L)913
CDCE906	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE706

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Digital X-Ray

Digital X-rays are revolutionizing diagnostic radiology and spurring innovative new applications, such as their use in surgical procedures. A key benefit of digital X-rays is the ability to store and transfer the digital images, allowing for the outsourcing of radiological services or easy access to remote and/or specialized analysis.

A conventional X-ray system captures less than 40 percent of the original image information. By adding a digital detector to digital X-ray imaging, it is possible to capture more than 80 percent of the original image information and use a wide range of post-processing tools to further improve the image.

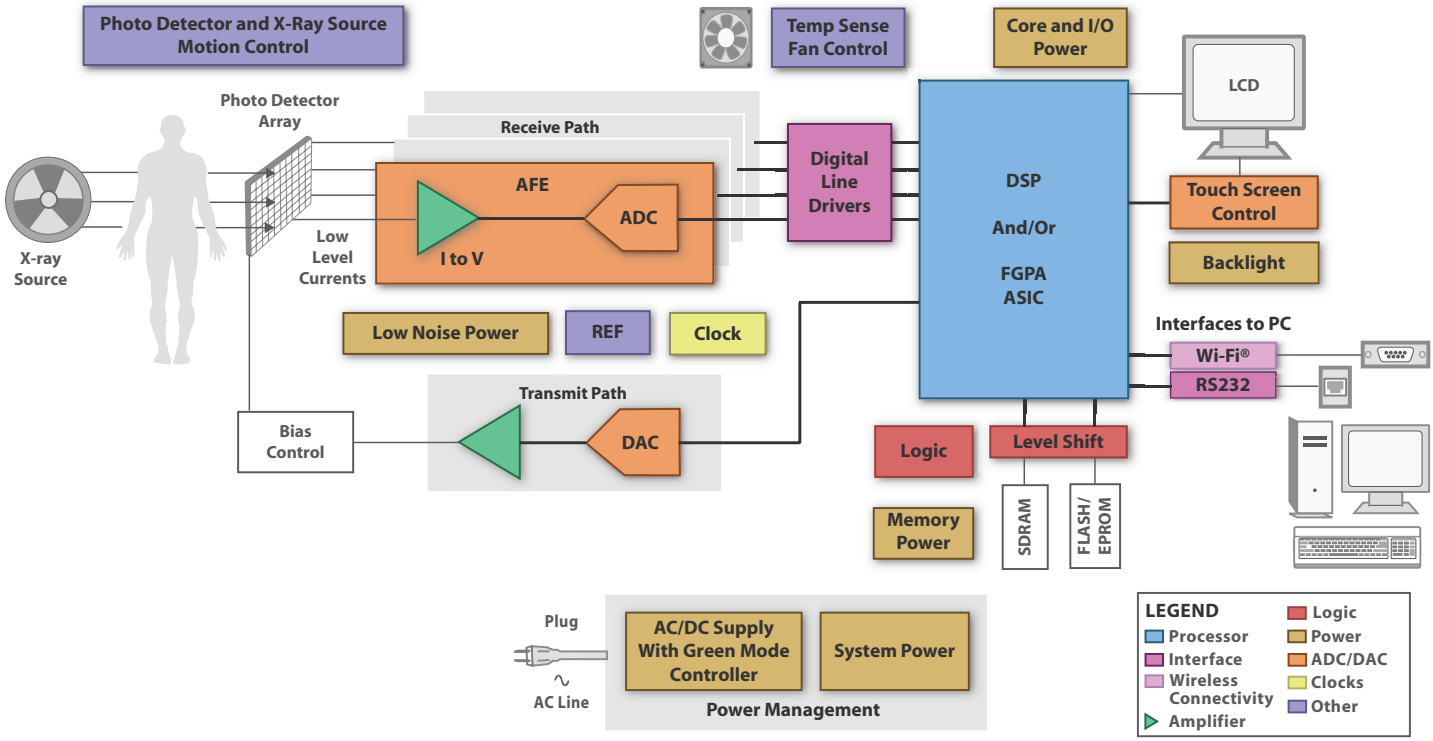
Other digital X-ray technology advances made possible by semiconductor technology include:

- Faster diagnoses by eliminating photographic processing time and facilitating quick transmission over network connections.
- Reduced costs by eliminating photographic processing film and chemicals.
- Processing only the image data that highlights regions of interest, suppressing irrelevant information.
- Combining image data with other pertinent radiology information system (RIS) and hospital information system (HIS) records.
- Archiving all relevant information efficiently.

There are two different approaches to digital X-ray technology: computed radiology (CR) and digital radiography (DR). Computed radiology involves trapping electrons on an imaging plate (IP) containing photo-stimulated-phosphor (PSP) and exposing them to generate image data. The IP is then moved to a CR reader, where it is scanned using a laser beam.

The second approach, digital radiography, uses both direct and indirect conversion. In direct conversion, flat-panel selenium detectors absorb X-rays directly and convert them into individual pixel electric charges. In indirect conversion, X-ray signals are converted to light, and then converted to electric charges. Both tiled charge-coupled device (CCD) arrays and computed tomography use indirect conversion technology. Tiled CCD transitional technology employs multiple CCDs coupled to a scintillator plate via fiber optics.

Computed tomography involves trapping electrons on photo-stimulated plates and exposing them to generate image data. In both approaches, charges



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Digital X-ray system block diagram.

Digital X-Ray

proportional to X-ray intensity seen by the pixel are stored in the thin film transistor (TFT) storage cap. A number of such pixels form the flat detector panel (FDP). The charges are deciphered by read-out electronics from the FDP and transformed into digital data.

The block diagram shows the readout electronics required for direct imaging to convert the charge in the FDP to digital data. It has two chains: the acquisition and the biasing chain. At the beginning of the acquisition chain, an analog front-end is capable of multiplexing the charges on different FDP (channels) storage caps and converting those charges into voltage. The biasing chain generates bias voltages for the TFT array through intermediate bias-and-gate control circuitry. Digital control and data conditioning are controlled by a DSP, an FPGA, an ASIC or a combination of these. These processors also manage high-speed serial communications with the external image processing unit through a high-speed interface (serialized, LVDS, optical).

Temperature sensors, DACs, amplifiers and high-input voltage-capable switching regulators are other key system blocks. Each block must have an enable pin and synchronize frequencies to avoid crosstalk with other blocks in the acquisition chain. The number of FDP pixels determines the number of ADC channels versus ADC speed. Static or dynamic acquisition also determines ADC speed. While static acquisition means a single image in less than 1 s, dynamic means an image is refreshed at 30 Hz for more specific cardiovascular, fluoroscopic or related applications that require much faster data conversion with the same number of channels. An ADC in the range of 2 MSPS or more with excellent DC performance will work well.

For indirect conversion, the CCD output requires correlated double sampling (CDS). The signal level's reset voltages and image signal level are converted to digital data by an analog front end (AFE). The AFE's sampling speed is determined by the number of pixels in the CCD array and the frame rate. In addition, the AFE corrects sensor errors such as dark current correction, offset voltages and defective pixels. Depending on the signal level, the presence of programmable gain amplifiers (PGAs), the linearity of the PGAs and the range of gains available may also be important. During digitization, the number of bits determines image contrast. Typically, digitizing the initial data with two to four bits more precision than desired in the final image is recommended. For example, if 8 bits of final image data are required, initially digitize to 10 bits to allow for rounding errors during image processing.

The main metric for image quality is detection quantum efficiency (DQE), a combination of contrast and SNR expressed in percentage. The higher the contrast and lower the noise, the higher the DQE. Contrast is the number of shades of gray determined by the ADC's output resolution. Generally, 14 or 16 bits are suitable for the application.

SNR indicates not only SNR from the ADC, but system SNR impact from X-ray dose, pixel size and all electronic components. SNR can be improved by increasing X-ray dose and photodiode spacing and decreasing electronics noise. Increasing the X-ray dose is not suitable for patients or operators. Increasing photodiode spacing may not be suitable because this decreases spatial resolution. Decreasing the noise from the system's electronics is the main challenge.

Total system noise is the root-square-sum of all noise contributions over the signal chain, assuming all are uncorrelated. This means all parts have to be ultra-low-noise or heavily filtered, when applicable, including ADCs, op amps and references. Stability over temperature is another important challenge. Internal temperature increases, due to power dissipation, may offset gray levels and distort an image, especially during dynamic acquisitions. Therefore, temperature stability of ADCs, op amps and references should be high.

The digital X-ray data undergoes several processing steps before it is presented to the display for viewing. The first step, called shading, is where the non-idealities in the detector pixels are corrected. Next, the unexposed area is determined in the detector so that it is not used in subsequent processing. Histogram equalization is then carried out on the useful data. Finally, several image enhancement techniques are used for noise reduction, contrast improvement and edge enhancement.

Product portfolio for digital X-rays

- Analog front ends (AFEs) capable of multiplexing the charges on different flat detector panels (FDPs), storage caps (channels) and converting these charges into voltage for direct conversion X-rays. AFEs also convert the signal level and its reset voltages to digital data and correct sensor errors in indirect conversion X-rays.
- High-performance DSPs for control functions and signal conditioning to acquire and improve the clarity of the image.
- Temperature sensors, DACs, amplifiers and high-input voltage-capable switching regulators are other key system blocks.

Digital X-Ray

64-Channel AFE

AFE0064

NEW

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/afe0064**

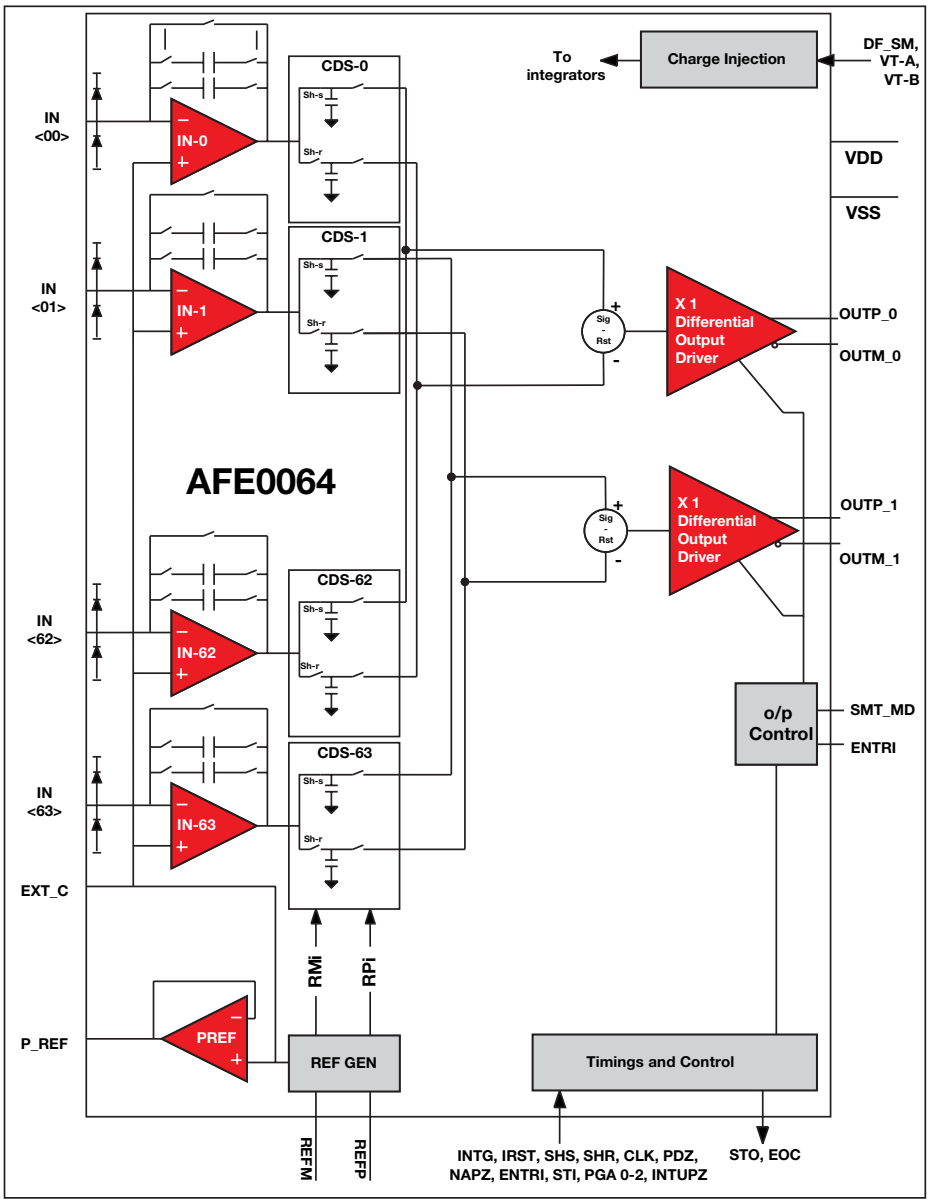
Key Features

- 64 channels
- 28.32µSec min scan time (including integration and data transfer for all 64 channels)
- 7.5MHz Max data transfer rate
- Noise 824 e-RMS with 30pF sensor capacitor in 1.2pC range
- Integral nonlinearity: ±0.006% of FSR
- Eight adjustable full scale ranges (0.13pC min to 9.5pC max)
- Built in CDS (signal sample – offset sample)
- Selectable integration up/down mode
- Low power: 175mW
- NAP mode: 49.5mW
- 14mm × 14mm 128 pin TQFP package

Applications

- Digital radiography
- Baggage scanners
- Infrared spectroscopy

The AFE0064 is a 64-channel analog front end designed to suit the requirements of flat panel detector-based digital X-ray systems. The device includes 64 integrators, a PGA for full scale charge level selection, correlated double sampler, 64 as to 2 multiplexer, and two differential output drivers. Hardware selectable integration polarity allows integration of a positive or negative charge and provides more flexibility in system design. In addition, the device features TFT (Thin Film Transistor from Flat Panel Detector) charge injection compensation. This feature helps maximize the usable signal charge range of the device.



AFE0064 functional diagram.

Digital X-Ray

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
AFE0064	64-Channel AFE	64 channel, 2.2 mW/ch, 14-15-bit linearity	Single ended integrator, ADC driver shared for 32 channels, external ADC	Glueless with external ADC
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA211	Precision Op Amp	1.1nV/$\sqrt{Hz}$ at 1kHz noise, 3.6mA/ch supply, 80MHz BW	Unity gain stable, RRO, shutdown	OPA227
OPA141	Precision Op Amp	10MHz, 6.5nV/$\sqrt{Hz}$, ±4.5V to ±18V, 1.8mA typical, FET input: I_B = 20pA max	Common mode voltage range includes GND	OPA827
OPA277	Precision Op Amp	10µV offset, ±0.1µV/°C drift, 134dB open-loop gain		OPA4277 (quad)
OPA827	Precision JFET Op Amp	4nV/$\sqrt{Hz}$ noise at 1kHz, ±4V to ±18V supply, 15pA (typ) input bias current, 22MHz BW	High precision, low noise, low input bias, wide supply range	OPA177, OPA627, OPA141
OPAx890	High-Speed Op Amp	Wide output swing of ±4.1 (V_S = ±5V)	Minimizes distortion when used as an ADC driver	OPA2890 (dual) OPA2889 (dual)
THS403x	High-Speed Op Amp	100MHz, 1.6nV/$\sqrt{Hz}$ noise, 100V/µs SR, 90mA output	Low distortion	THS4051, THS4081
THS413x	High-Speed Op Amp	150MHz (–3dB) BW, 51 V/µs SR, –100dB THD at 250kHz	Differential input/differential output	THS4120, THS4150
THS4520	High-Speed Op Amp	Fully differential, RRO	Minimizes distortion when used as an ADC driver	
Data Converters				
ADS8413	SAR ADC	16-bit, 2MSPS, serial LVDS	LVDS, serial interface, daisy-chain capable	ADS8410, ADS8406
ADS8422	SAR ADC	16-bit, 4MSPS, int. ref and ref buffer	Zero latency	ADS8412, ADS8472
DAC8814	Multiplying DAC	16-bit, 0.5µs settling time, –105dB THD, 1 LSB (max) relative ac-curacy	Double-buffered serial data interface	DAC7715, DAC8811
VSP2562	12-Bit, 36MSPS, 1-Channel Analog Front End	Low noise, OB correct 2X 8b DAC, PGA amplifier	Better image quality; corrects for sensor dark current offset; used for system tuning and control of analog functions. Programmable gain supports wide range of light conditions.	
VSP2582	12-Bit, 36MSPS, 1-Channel Analog Front End	Low noise, OB correct PGA amplifier	Better image quality; corrects for sensor dark current offset. Programmable gain supports wide range of light conditions.	
Interface				
SN65EL11	PECL/ECL 1:2 fanout Buffer	Differential 1:2 PECL/ECL fanout buffer	Maintains a known logic level when inputs are in an open condition	SN65MLVD047
SN65ELT20	5 V TTL to Differential PECL Translator	1.25ns max prop delay	Built-in temperature compensation	SN65ELT21
SN65LV1023A	10:1 LVDS Serdes	Embedded clock	Smallest package	SN65LV1224B
SN65LVDS31	4-Channel LVDS Driver	400Mbps	Industry standard	SN65LVDS32
TLK6201EA	PC Board Equalizer	Up to 6.25Gbps operation, low power, high-input dynamic range	CML data outputs	
Clocking				
CDCLVP12xx/ 21xx	1:2/4/8/12/16 or Dual 1:2/4/6/8 Universal-to-LVPECL Clock Buffers	Very low additive jitter <100ps RMS; 2.5V / 3.3V operation	Improved clock signal quality by 10x; saves additional interface logic / external components	CDCLVP111, CDCLVP215
Temperature Sensor				
TMP175	Digital Temp Sensor	27 addresses, ±1.5°C (max) accuracy, 50µA I_Q, 9- to 12-bit resolution	Two-wire interface, serial output	TMP75
TMP275	Digital Temp Sensor	8 addresses, ±0.5°C (max) accuracy, 50µA I_Q, 9- to 12-bit resolution	Two-wire interface, serial output	

*To view more system block diagram compatible products, visit **www.ti.com/healthtech***

*New products are listed in **bold red**.*

Digital X-Ray

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
AM37x	Applications Processor	ARM® Cortex-A8 processor that nearly doubles graphics performance and overall system performance while providing a 30 percent decrease in power consumption	Laptop-like performance at handheld power levels	AM3715, AM3703
TMS320C-6455BZTZ	DSP	1.2GHz, SRIO, 2MB RAM	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6472	DSP	6 x 700MHz C64x+ cores, 4.8MB RAM, SRIO, HPI	High-performance multiprocessor solution	
TMS320C6474	DSP	3 x 1GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6655	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x single core, 2MB L2, 2.5W	Fixed and floating point DSP, 20 GFlops, 40 GMACS	
TMS320C6657	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x dual core, 2MB L2, 3.5W	Fixed and floating point DSP, 40 GFlops, 80 GMACS	
TMS320C6678	Industry's Highest Performance Floating-Point DSPs	1.0, 1.25 GHz, eight C66x cores, 8MB L2, 10W	High-performance fixed and floating point DSP, 160 GFlops, 320 GMACS	
TMS320F2810	DSP	150MIPS, controller area network (CAN) peripheral	CAN for board-level communication, combination of DSP performance and MCU integration	
TMS320DM-6446BZWT	DSP	C64x+™, ARM9, video accelerators	Image processing, display	TMS320DM6441, TMS320DM6437
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF50xx	High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V, 10V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Positron Emission Tomography (PET) Scanners

Positron emission tomography (PET) is a non-invasive diagnostic technology. Used to identify growing cancer cells, for example, a PET scan uses radiation emissions from the body (generated by radioactive chemical elements consumed by the patient) to produce physiologic images of specific organs or tissues.

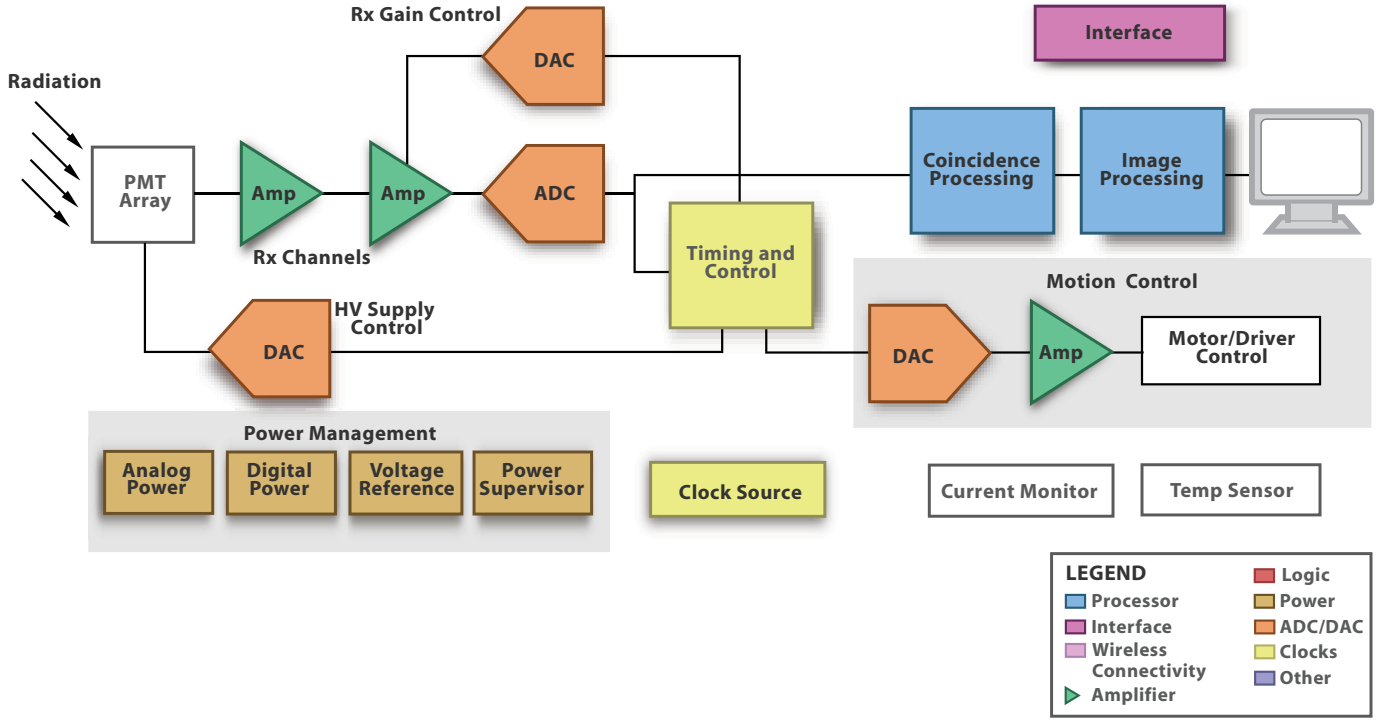
The radioactive emissions are converted to light via a scintillation crystal detector and are amplified and converted to an output current by a photomultiplier tube (PMT). The PMT's current output is then converted to a voltage that is amplified and filtered before being converted to a digital signal by an ADC.

Signal processing is needed for detector signal processing of the receive channels and for a number of control functions. DSPs, microcontrollers and digital-to-analog converters are used in this application for functions such as varying input amplifier gain, controlling the PMT high-voltage power supply, and motion control for the detector ring assembly and patient entry/exit.

DSPs can be used for PET scanner control and signal processing units. Filtered back-projection algorithms can be used in image reconstruction. Several iterative techniques have also been proposed for PET image reconstruction. Additional signal pre-conditioning may be necessary to correct various artifacts like attenuation variations, detector geometry and efficiency variations, random and scatter coincidences, etc.

Product portfolio for PET scanners

- Amplifiers, power management products and other analog parts are suitable for converting radioactive emissions to light and reconstruct and correct images.
- DSPs such as the TMS320C6455 can handle tasks such as varying input amplifier gain and controlling the photomultiplier tube (PMT) high-voltage power supply and motion control for detector ring assembly and patient entry/exit. DSPs are also suitable for PET scanner control and signal processing units.



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

PET scanner system block diagram.

Positron Emission Tomography (PET) Scanners

8-Channel, Ultra-Low-Power, 12- and 10-Bit, 50 to 65MSPS Analog-to-Digital Converters with Serialized LVDS Interface

ADS5281, ADS5282, ADS5287

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **ads5281**, **ads5282** or **ads5287**)

Key Features

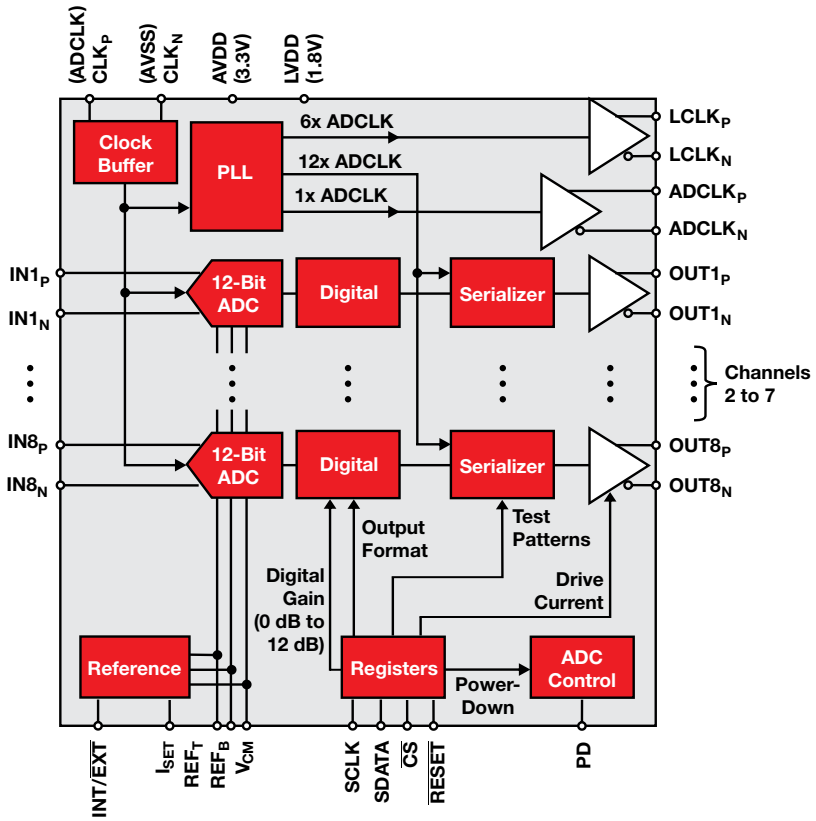
- 8-channel 12- or 10-bit ADCs in one small 64-pin QFN package
  - ADS5281 also available in 80-pin TQFP pin-compatible to ADS527x
- 77mW per channel at 65MSPS; 64mW per channel at 50MSPS
- 70dB SNR for 12-bits at 10MHz IF
- 1/f (flicker) noise suppression
- Up to 6dB overload recovery in one clock cycle
- Individual channel power down
- Direct interface with VCA8500 8-channel variable-gain amplifier
- Xilinx-supported deserializer code

Applications

- Medical and other imaging:
  - Ultrasound
  - MRI
  - PET

The ADS5281 family provides eight high-performance ADCs in a small 64-pin QFN package, making it possible to implement high channel counts in high-performance ultrasound and other medical imaging systems. The low power dissipation per channel aids in making compact ultrasound equipment where space and battery life are at a premium, and in conjunction with the VCA8500 offers a high-performance LNA-to-digital solution for less than 130mW per channel in ultrasound applications.

The ADS5281 family also incorporates advanced features to optimize system performance, including programmable gain from 0 to 12dB in 1dB steps, 1/f (flicker) noise suppression and 6dB input overload recovery within one clock cycle. Available with 12-bit resolution at 50 and 65MSPS and 10-bit resolution at 65MSPS, the ADS5281 family has the flexibility to offer an optimal solution for the entire spectrum of imaging systems.



ADS5281/2/7 functional diagram.

Positron Emission Tomography (PET) Scanners

Wideband, >40dB Gain Adjust Range Variable-Gain Amplifier

VCA821

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/vca821**

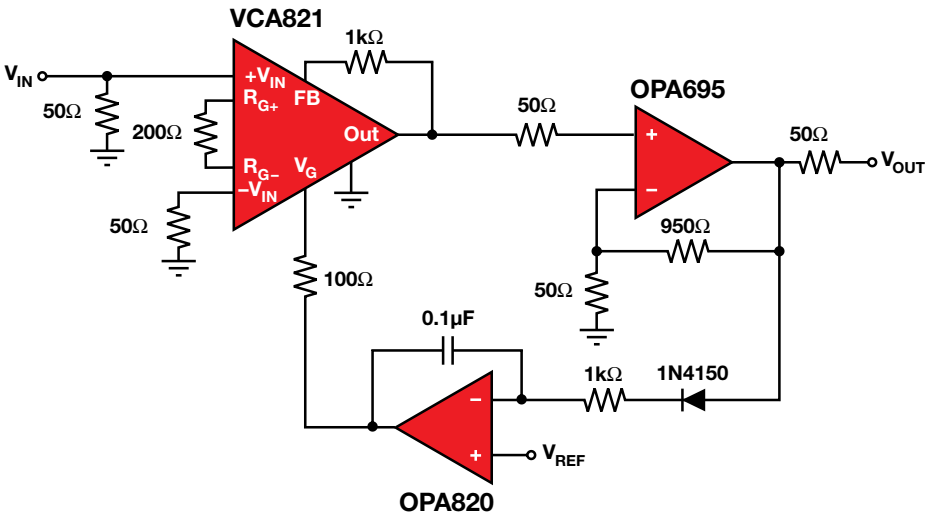
Key Features

- >40dB gain adjust range
- High gain accuracy: 20dB ±0.4dB
- Small signal bandwidth (G = +2): 710MHz (VCA821/824), 150MHz (VCA820/822)
- Slew rate: 2500V/µs (VCA821/824), 1700V/µs (VCA820/822)
- Output current: ±160mA (VCA820/822), ±90mA (VCA821/824)
- Voltage noise: 8.2nV/√Hz (VCA820/822), 6nV/√Hz (VCA821/824)
- Packaging: MSOP-10, SO-14

Applications

- AGC receivers with RSSI (VCA820/821)
- Pulse amplitude compensation
- Differential line receivers
- Differential equalizers (VCA822/824)
- Voltage-tunable active filters
- Variable attenuators

The VCA821 is a DC-coupled, wideband, variable-gain amplifier with linear gain adjustment control for >40dB gain range. This amplifier provides a differential input to single-ended conversion with a high-impedance gain-control input used to vary the gain with linear in dB gain adjust. The output voltage of ±3.9V and current capability of ±90mA helps drive a large variety of loads. Also available from this variable-gain family are the VCA820, offering linear in dB gain adjust, and the VCA822 and VCA824, offering linear in V/V gain adjust.



Variable-gain amplifier with AGC loop.

Positron Emission Tomography (PET) Scanners

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32 Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
OPA657	High-Speed Op Amp	FET-Input, 1.6GHz GBW, 4.8nV/√Hz noise, 70mA output	High dynamic range, fast overdrive recovery	
OPA860	Transconductance Amp	80MHz, open loop, G = +5 BW, 900V/µs SR	95mA/V high transconductance, buffer	
OPA827	Precision JFET Op Amp	4nV/√Hz noise at 1kHz, ±4V to ±18V supply, 15pA (typ) input bias current, 22MHz BW	High precision, low noise, low input bias, wide supply range	OPA141, OPA177, OPA627
OPA211	Precision Op Amp	1.1nV/√Hz noise at 1kHz, ±2.25V to ±18V supply, 80MHz BW	Unity gain stable, RRO, wide supply range	OPA227
OPA2690	VFB Op Amp	Dual, 220MHz, G = 2 BW, 1800V/µs SR, 190mA output	+5V supply, disable	OPA2691
THS4130	High-Speed Op Amp	150MHz BW (–3dB), 51V/µs slew rate, –100dB THD at 250kHz	High-speed, fully differential I/O	
THS7530	High-Speed VGA	1.1nV/√Hz noise, 300MHz BW, 11.6dB to 46.5dB continuously variable gain	High-speed, fully differential	
VCA810	Voltage-Controlled Amp	±40dB high gain adjust range, 2.4nV/√Hz noise, ±60mA output current	Differential in/single-ended out	
VCA821	Voltage-Controlled Amp	>40dB gain adjust range with high gain accuracy	Adds flexibility and accuracy to design	VCA820
Data Converters				
ADS5240	High-Speed ADC	4-channel, 12-bit, 40MSPS, serial LVDS interface	Integrated frame and bit pattern, 4 current modes for LVDS	ADS5242, ADS5525
ADS5272	High-Speed ADC	8-channel, 12-bit, 65MSPS, 3.3-V analog/digital supply	Serialized LVDS outputs, integrated frame and bit patterns	
ADS5281	High-Speed ADC	8-channel, ultra-low-power, 12- and 10-bit, 50 to 65MSPS analog-to-digital converter	77mW per channel, serialized LVDS outputs, 1/F noise-suppression	ADS5282, ADS5287
ADS5282	High-Speed ADC	Ultra-low-power, 8-channel, 12-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281, ADS5287
ADS5287	High-Speed ADC	Ultra-low-power, 8-channel, 10-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281, ADS5282
ADS5525	High-Speed ADC	12-bit, 170MSPS, DDR/LVDS CMOS outputs	Programmable gain up to 6dB for SNR/SFDR trade-off at high IF	ADS5527, ADS5545
ADS5527	High-Speed ADC	12-bit, 210MSPS, DDR/LVDS CMOS outputs	Internal/external reference support	ADS5545, ADS5440
ADS5562	High-Speed ADC	Low-power, 16-bit ADC with up to 84dBFS SNR	High SNR, 1/f noise suppression with low power and small package	ADS5560
DAC2900	High-Speed DAC	10-bit, 125MSPS dual DAC	Supports 3.3/5V	DAC2902, DAC2904
DAC5652	High-Speed DAC	10-bit, 275MSPS dual DAC	High sample rate with low power	DAC5662, DAC5672
DAC7554	V_{OUT} DAC	Quad, 12-bit, 2.7V to 5.5V supply, 5µs settling time	Ultra-low glitch, ultra-low crosstalk	DAC7614, DAC7615
DAC7731	V_{OUT} DAC	16-bit, 150mW (max) low power, 5µs settling time, +10V int. reference	Unipolar or bipolar operation	DAC8811
References				
LM4040x	Precision Micropower Shunt Voltage Reference	35µV_{RMS} typ, ABCD grade, 45µA (typ) to 15mA 2.048V, 2.5V, 3V, 4.096V, 5V, 8.192V, 10V	Highly precise with low output noise and a wide operating current range	
REF02	Precision V_{REF}	0.2% (max) initial accuracy, 10ppm/°C (max) drift, 1.4mA (max)	Excellent line/load regulation, low noise	REF5050
REF102	10V, Ultra Precision	0.05% (max) initial accuracy, 2.5ppm/°C (max) drift, 1.4mA (max)	Excellent stability and line/load regulation	REF5010
REF31xx	Voltage Reference	15-ppm/°C (max) drift, 5mV low dropout, 115µA (max) I_Q, 0.2% (max) accuracy, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	No load capacitor required	REF3130, REF3120
REF32xx	Low Drift, Bandgap	0.2% (max) accuracy, 7ppm/°C (max) drift, 0.1mA (max) I_Q, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V	Multiple output voltages, SOT23-6	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Positron Emission Tomography (PET) Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
REF33xx	Very-Low-Power Series Reference	5µA, 0.15% initial accuracy, 30ppm/°C max drift, ±5mA output, 1.25V, 1.8V, 2.048V, 2.5V, 3.0V, 3.3V	Preserves battery life, fits into physically constrained systems	REF30xx, REF31xx, REF29xx
REF5010	10V, High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 10V	Improves system accuracy	REF102
REF50xx	High-Precision, Very-Low-Drift Series Reference	0.05% initial accuracy, 3ppm/°C max drift, ±10mA output, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5.0V	Improves system accuracy	REF02
TL43x	Adjustable Precision Shunt Regulator	Output voltage V_{REF} to 36V, 0.2-Ω (typ), sink-current capability 1mA to 100mA	Easy to use, low output noise, great replacement for Zener Diodes	
Interface				
SN65EL11	PECL/ECL 1:2 Fanout Buffer	Differential 1:2 PECL/ECL fanout buffer	Maintains a known logic level when inputs are in an open condition	SN65MLVD047
SN65LVCP40	Dual 1:2 Mux/Buffer	Input EQ, output pre-emp	Improves signal range	SN65LVCP404
SN65LVDS93A	24-Bit RGB LVDS Serdes	10MHz-135MHz, BGA and TSSOP; supports 1.8V to 3.3V TTL i/p	Wide frequency range, saves space, no level shifter for 1.8V powered uP	SN75LVDS83B
TLK1221	Gigabit Ethernet Serdes	Power 250mW	Smallest package	TLK2208B
Clocking				
CDCE62005	Clock Generator	rms jitter <1ps, recommended clocking solution for AFE580x and ADS528x/527x	Integrated VCO saves system cost	CDCE72010, CDCM7005
CDCE(L)949	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE(L)937, CDCE(L)925, CDCE(L)913
CDCE906	Clock Synthesizer	Recommended clocking solution for TI DSPs	0ppm multiple-frequency generation	CDCE706
CDCLVP12xx/ 21xx	1:2/4/8/12/16 or Dual 1:2/4/6/8 Universal-to-LVPECL Clock Buffers	Very low additive jitter <100ps RMS; 2.5V/3.3V operation	Improved clock signal quality by 10x; saves additional interface logic / external components	CDCLVP111, CDCLVP215
Processors				
TMS320C6452	DSP	900MHz, 1.4MB L2 cache, 2 x S GMII/Gigabit EMAC	High-performance DSP with improved system cost	
TMS320C-6455BZTZ	DSP	1.2GHz, SRIO, 2MB RAM	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6472	DSP	6 x 700Mhz C64x+™ cores, 4.8MB RAM, SRIO, HPI	High-performance multiprocessor solution	
TMS320C6474	DSP	3 x 1GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6452	DSP	900MHz, 1.4MB L2 cache, 2 x S GMII/Gigabit EMAC	High-performance DSP with improved system cost	
TMS320C-6455BZTZ	DSP	1.2GHz, SRIO, 2MB RAM	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6472	DSP	6 x 700Mhz C64x+™ cores, 4.8MB RAM, SRIO, HPI	High-performance multiprocessor solution	
TMS320C6474	DSP	3 x 1GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6655	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x single core, 2MB L2, 2.5W	Fixed and floating point DSP, 20 GFlops, 40 GMACS	
TMS320C6657	Industry's Most Efficient Floating-Point DSPs	1.0, 1.25 GHz, C66x dual core, 2MB L2, 3.5W	Fixed and floating point DSP, 40 GFlops, 80 GMACS	
TMS320C6678	Industry's Highest Performance Floating-Point DSPs	1.0, 1.25 GHz, eight C66x cores, 8MB L2, 10W	High-performance fixed and floating point DSP, 160 GFlops, 320 GMACS	

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Optical 3-D Surface Scanners

DLP® technology facilitates 3D measurement by utilizing a DMD (Digital Micromirror Device) as a spatial light modulator. The DMD achieves high quality, fast, and flexible sequential pattern illumination of the subject field. Typically, solid state (LED) illumination is used to provide monochrome or multi-color, high brightness illumination within the visible to NIR wavelength range.

Example uses for 3D imaging in the medical industry include scanners for: dental scanners, inner-ear scanners for hearing aids, foot scanners for podiatrists, limb scanners for prosthetics, skin measurement for wound healing and cosmetics, and face/body scanning for plastic surgery.

A synchronized camera of sufficient resolution, sensitivity, and capture frame rate is required to complete the 3D measurement loop. The DMD controller provides a SYNC output to trigger the camera shutter for capturing each pattern in sequence.

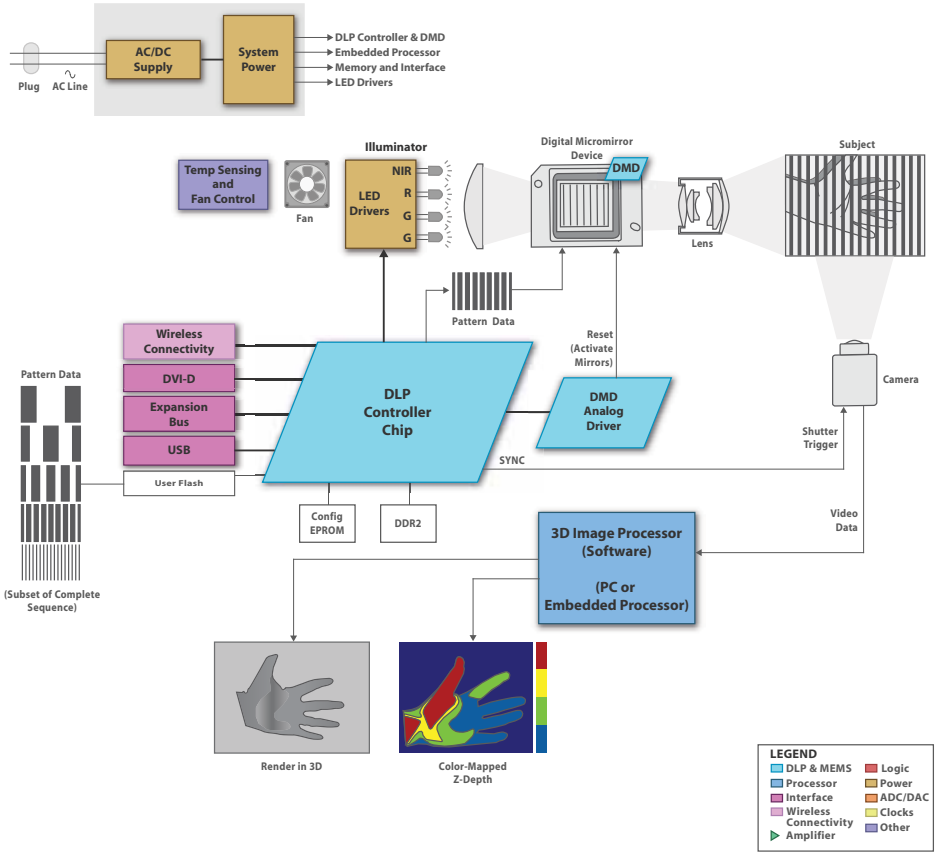
The 3D measurement depends on the principle of geometric triangulation. This requires a certain amount of baseline offset between the pattern projection lens and the camera lens, with both lenses aimed at the subject field. Provision should be made for securely locating the projection and camera optics so that measurement calibration can be established and maintained.

The chosen measurement algorithm determines the type and number of patterns used. Patterns may be binary or “gray scale” (the operation of the two is somewhat different). The essential principal is multi-scale (coarse to fine) image analysis. The measurement algorithm, and the type and number of patterns used will affect the speed, resolution, and accuracy of the measurements.

The measurement algorithm is implemented in software and executed on a PC or embedded processor. The output of the measurement algorithm can take several forms. One example is a color-coded z-depth map. Another is a point cloud (set of measurements) which can be processed by 3D visualization programs, such as MeshLab.

The sequence of patterns required for a full measurement take a finite period of time to occur. The subject must be held immobile (still) during the measurement time in order to avoid blurring, striping, and measurement errors. Faster pattern rates allow for fewer motion artifacts and errors.

The speed and effectiveness of the 3D measurement system depend on illumination brightness and ambient light levels. In general, brighter illumination allows for faster measurements. The LED illuminators (and electrical drivers) require sufficient consideration of power and thermal factors to allow for proper operation and reliability for the expected environmental conditions.



DLP® 3D Biometrics system block diagram.

Hyperspectral Imaging

Hyperspectral imaging employs a dispersive optical element to spread the spectrum of light into spatially separated wavelengths. The dispersive element is usually a diffraction grating, which can be optimized for different spectral regions (UV, visible, NIR, etc.).

The Hyperspectral application illustrated in the diagram shows an external scene being focused by an imaging lens (like that used in an ordinary camera) on a DLP® Digital Micromirror Device (DMD). The DMD is used to decompose the image by turning on a single mirror at a time, until the entire image has been examined. The light reflected from each mirror (corresponding to each "pixel" in the scene) is collected and shined on a diffraction grating, which spreads the light out into a precisely dispersed spectrum of different wavelengths. The dispersed light is detected by a CCD (or CMOS) sensor array similar to that used in a camera, but in this case it is capturing the spectrum of each pixel, rather than capturing a broad-spectrum image of the 2 dimensional scene all at once. There is no correspondence between points in the scene, and points in the sensor array. The points in the sensor array correspond to each specific wavelength dispersed by the diffraction grating.

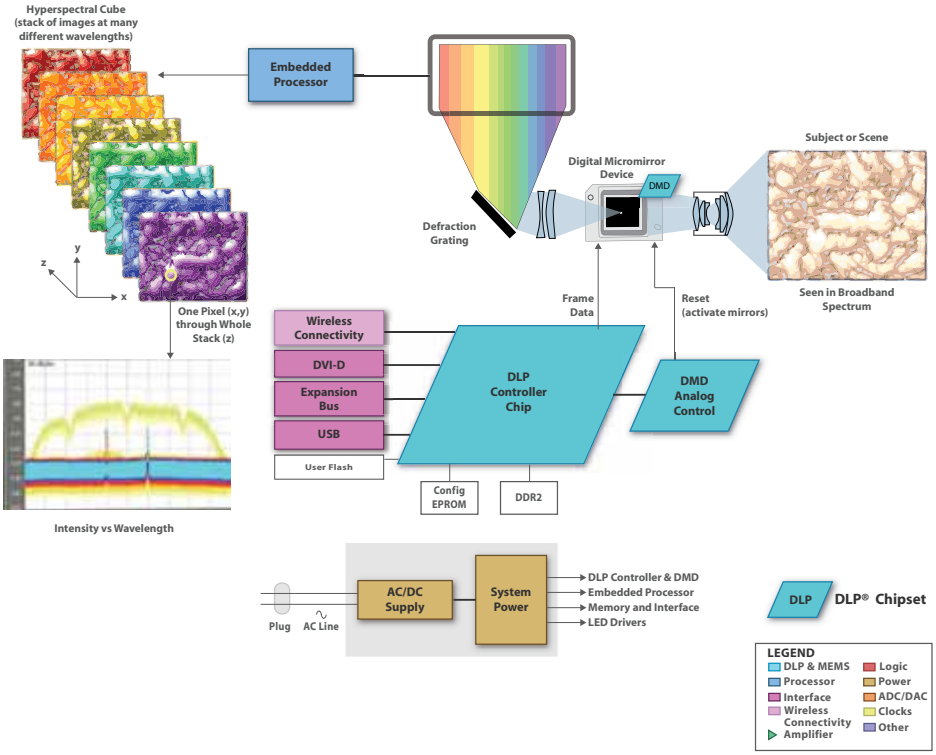
The embedded processor has two functions. The first is to send the commands to the DMD controller to turn on only the precise mirror at each instant to scan (or decompose) the image and send each pixel of the image to the diffraction grating. The second function of the embedded processor is to collect the data from the sensor and assemble the data into the Hyperspectral cube as the entire scene is scanned.

It is interesting to note that the data in the Hyperspectral cube can be viewed as a graph of the light intensity vs. wavelength at each point in the scene. Just as with traditional spectroscopy, the distinctive shape of this curve constitutes a spectral signature of the material being examined. By comparing the spectral signature of the sample to stored reference signatures, it is possible to ascertain the physical and chemical composition of the sample.

The diagram shows a DLP chipset, which includes the DMD, and a DMD Controller chip, plus a DMD Analog Control chip (depending on the specific DLP chipset). Choosing a DLP chipset will depend on the Hyperspectral imaging system's specifications, such as the range of wavelengths to be measured, the resolution of the image needed, the speed of acquisition of a Hyperspectral cube, etc.

The choice of sensor array device will depend, again, on the range of wavelengths to be measured. Other considerations for the sensor include the required sensitivity, speed of acquisition, noise, temperature range, interface requirements, cost, and other factors.

The system control and signal processing is accomplished by the Embedded Processor (Such as TI OMAP®). Power is provided by TI Power devices. An actual product will require additional optical components and optical design in order to achieve full functionality.



Hyperspectral Imaging system block diagram.

Endoscopes

In medicine, an endoscope is used to look inside the body to examine organs. Through a small incision, endoscopes can examine gastrointestinal, respiratory and urinary tracts, as well as internal organs. An endoscope captures images through its long tube, which can be rigid or flexible. Additional instruments for cutting, grasping and other functions are often attached to the endoscope to permit minimally invasive procedures that improve patient care and minimize recovery time.

When used in a technical application to inspect confined spaces, the tool is often referred to as a borescope. Borescopes are used to inspect machinery interiors, building walls and to search for victims in collapsed buildings.

Endoscopes and borescopes have four basic requirements:

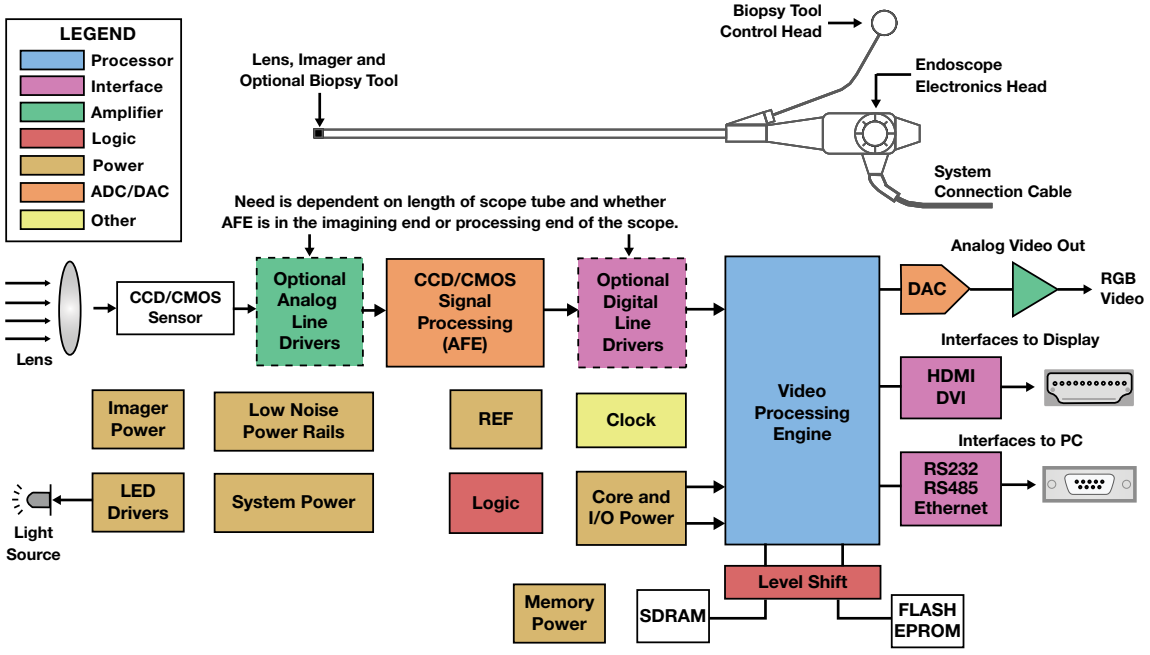
- A light source to illuminate the subject
- A tube to guide the light to the subject
- A lens or fiber optic system to capture light reflected from the subject
- An image-capture system to capture, process and store or display the image

TI's broad product portfolio supports the entire image chain including generating light, capturing an image, signal conditioning and image processing. LED drivers supply a bright light source with excellent directionality and minimal waste heat. These drivers are versatile and permit LED selection optimized for an application's spectral requirements. The resolution of current steps impacts illumination control precision: PWM and analog dimming available from TI LED drivers allow for precise illumination level and timing control.

The image sensor detects reflected light and converts the light to an analog electrical signal. Depending on the image sensor's location, low-noise line drivers may be needed to transmit the signal over the light tube's length. Critical considerations for line drivers are low power, noise immunity and data rate. LVDS technology provides up to 800 Mbps with voltage swings of a few tenths of a volt and high rejection of common-mode noise.

Essential to final image quality is the analog front end (AFE). The AFE conditions the sensor's analog electrical signal and converts image information to a digitized representation. Critical to AFE selection is the ability to condition the signal to correct sensor-induced distortions such as dark current cancellation, reset level variations, defective pixel correction and DC offset variations. Depending on the signal level, the presence of programmable gain amplifiers (PGAs), PGA linearity and the range of available gains may also be important. During digitization, the number of bits determines image contrast. Typically, digitizing the initial data with two to four bits more precision than desired in the final image is recommended. For example, if 8 bits of final image data are required, initially digitize to 10 bits to allow for rounding errors during image processing. When color reproduction is critical, differential non-linearity (DNL) and integral non-linearity (INL) should be minimized.

For more information, visit www.ti.com/endoscope



Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

Endoscope system block diagram.

Endoscopes

Digital Media System-on-Chip

TMS320DM368

For more information, visit: **www.ti.com/sc/device/tms320dm368**

Key Features

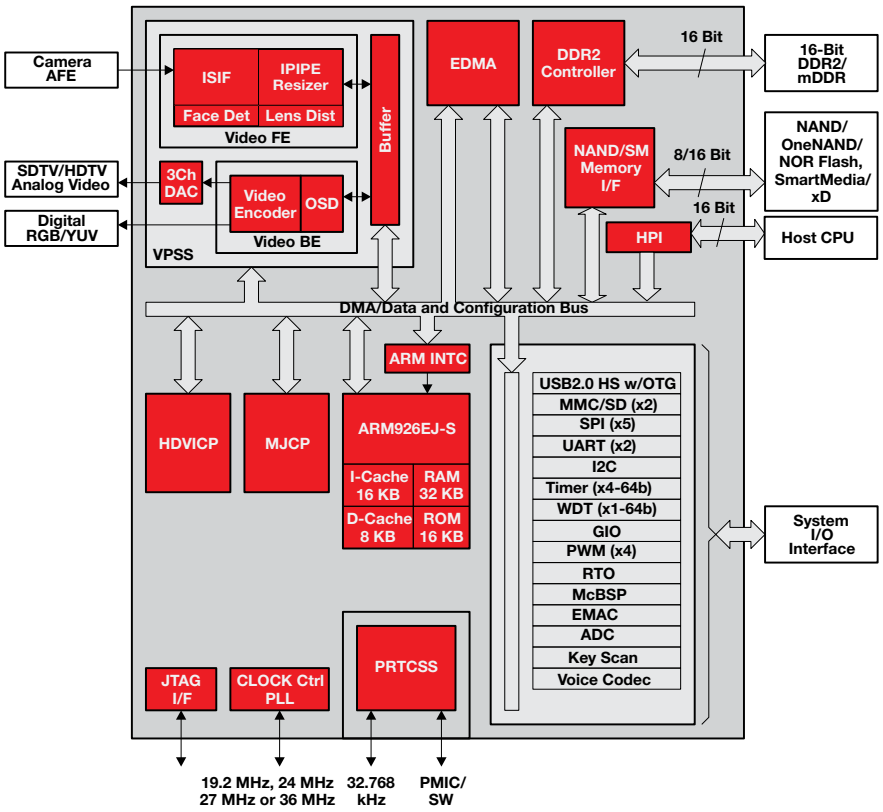
- HD video processing at 1080p 30 fps H.264
- 432-MHz ARM926EJ-S clock rate
- Two video image co-processor (HDVICP, MJCP) engines
- 3.3-V and 1.8-V I/O, 1.35-V core
- Extended temperatures available

Applications

- DLP® spectroscopy
- Endoscope

Developers can now deliver crystal clear multi-format video at up to 1080p H.264 at 30 fps (encode and closed-looped decode) in their designs without concerns of video format support, constrained network bandwidth, limited system storage capacity or cost with the new TMS320DM368 DaVinci™ video processor from Texas Instruments.

The DM368 is capable of achieving HD video processing at 1080p 30fps H.264 and is completely pin-to-pin compatible with the DM365 processors, using the same ARM926EJ-S core running at 432 MHz. This ARM9-based DM368 device supports production-qualified H.264BP/MP/HP, MPEG-4, MPEG-2, MJPEG and VC1/WMV9 codecs, providing customers with the flexibility to select the right video codec for their application.



TMS320DM368 system block diagram.

Endoscopes

16-Bit Ultra-Low-Power MCU

MSP430F4481

For more information, visit: **www.ti.com/sc/device/msp430f4481**

Key Features

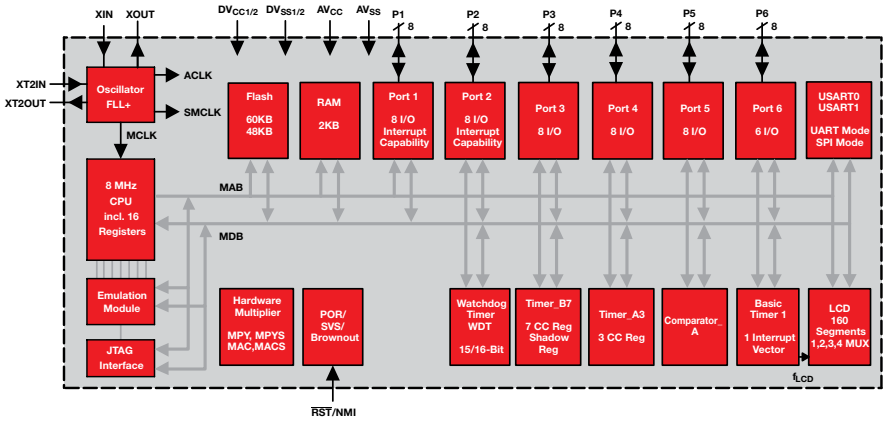
- Low supply-voltage range, 1.8 V to 3.6 V
- Ultra-low-power consumption
- 2-bit A/D converter with internal reference
- 16-bit RISC architecture
- Supply voltage supervisor/monitor with programmable level detection

Applications

- Endoscope

The device architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6 µs.

The MSP430F4481 has a configuration with two built-in 16-bit timers, one or two universal serial synchronous/asynchronous communication interfaces (USART), 48 I/O pins, and a liquid crystal driver (LCD) with up to 160 segments.



MSP430F4481 system block diagram.

Endoscopes

5-Channel Power Mgmt IC

TPS65053

For more information, visit: **www.ti.com/sc/device/tps65053**

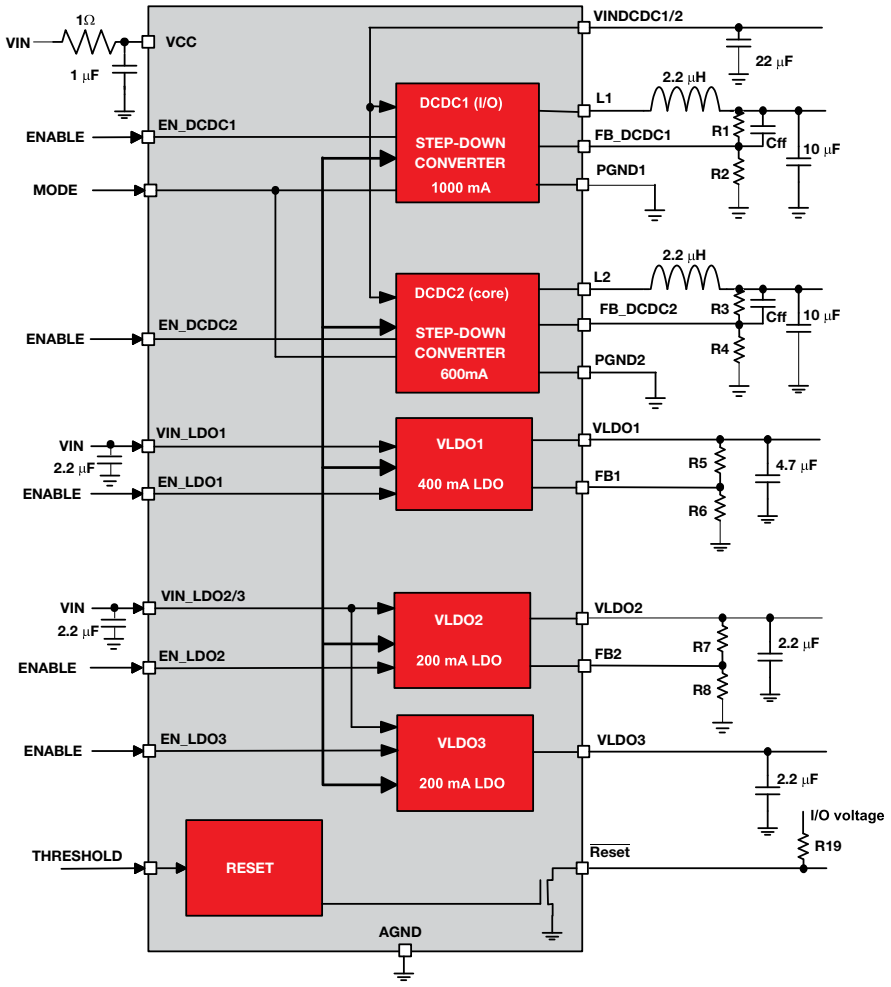
Key Features

- Up to 95% efficiency
- 2.5 V to 6 V V_{IN} range for DC/DC converters
- 2.25-MHz fixed frequency operation
- Output current of up to 1 A on the DC/DC1 converter
- 180° out-of-phase operation
- Output voltage accuracy in PWM mode ±1%
- Total typical 32-µA quiescent current for both DC/DC converters
- 100% duty cycle for lowest dropout

Applications

- Oscilloscope
- Pulse oximetry

The TPS65053 is an integrated Power Management IC for applications powered by one Li-Ion or Li-Polymer cell, which require multiple power rails. The device provides two highly efficient, 2.25 MHz step-down converters targeted at providing the core voltage and I/O voltage in a processor based system. Both step-down converters enter a low power mode at light load for maximum efficiency across the widest possible range of load currents. For low noise applications the devices can be forced into fixed frequency PWM mode by pulling the MODE pin high. Both converters allow the use of small inductors and capacitors to achieve a small solution size. TPS65053 provides an output current of up to 1 A on the DC/DC1 converter and up to 0.



TPS65053 system block diagram.

Endoscopes

1A SIMPLE SWITCHER® Nano Module

LMZ10501

For more information, visit: **www.ti.com/sc/device/lmz10501**

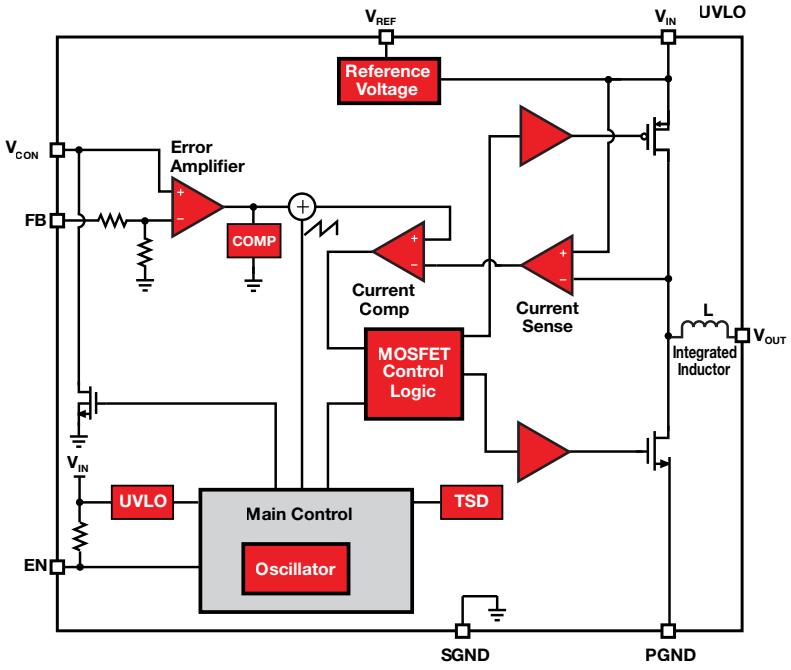
Key Features

- Easy-to-use step-down DC/DC solution
- Drive up to 1 A load
- Point-of-load conversions from 3.3 V and 5 V rails

Applications

- Endoscope
- Low output noise applications
- Space constrained applications

The LMZ10501 SIMPLE SWITCHER® nano module is an easy-to-use step-down DC/DC solution capable of driving up to 1 A load in space-constrained applications. Only an input capacitor, an output capacitor, a small V_{CON} filter capacitor, and two resistors are required for basic operation. The nano module comes in 8-pin LLP footprint package with an integrated inductor. Internal current limit based soft-start function, current overload protection, and thermal shutdown are also provided.



LMZ10501 system block diagram.

Endoscopes

525 kHz/1.6 MHz Constant Current Boost and SEPIC LED Driver

LM3410

For more information, visit: **www.ti.com/sc/device/lm3410**

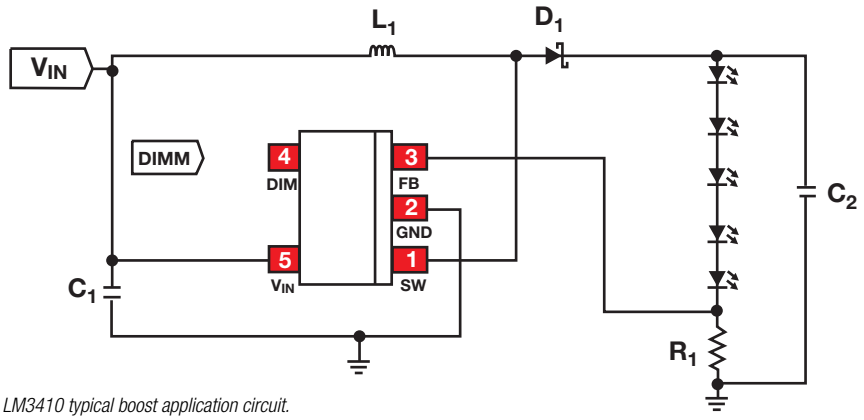
Key Features

- Input voltage range of 2.7 V to 5.5 V
- Output voltage range of 3 V to 24 V
- 2.8 A typical switch current
- High switching frequency
- Thermal shutdown
- 190 mV internal voltage reference

Applications

- Endoscope

The LM3410 constant current LED driver is a monolithic, high frequency, PWM DC/DC converter in 5-pin SOT23, 6-pin LLP, & 8-pin eMSOP packages. With a minimum of external components the LM3410 is easy to use. It can drive 2.8A typical peak currents with an internal 170 mΩ NMOS switch. Switching frequency is internally set to either 525 kHz or 1.60 MHz, allowing the use of extremely small surface mount inductors and chip capacitors. Even though the operating frequency is high, efficiencies up to 88% are easy to achieve. External shutdown is included, featuring an ultra-low standby current of 80 nA. The LM3410 utilizes current-mode control and internal compensation to provide high-performance over a wide range of operating conditions. Additional features include dimming, cycle-by-cycle current limit, and thermal shutdown.



LM3410 typical boost application circuit.

Endoscopes

Three 10-Bit Video DAC

THS8135

For more information, visit: **www.ti.com/sc/device/ths8135**

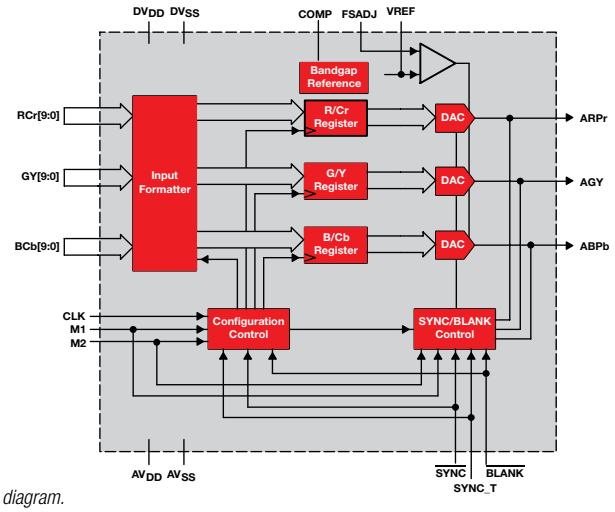
Key Features

- Operates from 3.3-V analog and 1.8-V digital supplies
- 240-MSPS operation
- Three 10-bit D/A converters
- YPbPr/RGB configurable blanking levels
- Integrated sync-on-green/luminance or sync-on-all composite sync insertion
- Internal voltage reference
- Low-power operation From 3.3-V analog and 1.8-V digital supply levels

Applications

- Endoscope

The THS8135 is a general-purpose triple high-speed D/A converter optimized for use in video/graphics applications. The device operates from 3.3-V analog and 1.8-V digital supplies. The THS8135 performance is assured at a sampling rate up to 240 MSPS. The THS8135 consists of three 10-bit D/A converters and additional circuitry for bi-level/tri-level sync and blanking level generation. By providing a DC offset for the lowest video amplitude output in video DAC mode, the device can insert a (negative) bi-level or (negative/positive) tri-level sync on either only the green/luminance (sync-on-green/sync-on-Y) channel or on all channels for video applications. A generic DAC mode avoids this dc offset, making this device suitable for non-video applications as well.



THS8135 system block diagram.

3G/HD/SD Video Clock Generator with Audio Clock

LMH1983

For more information, visit: **www.ti.com/sc/device/lmh1983**

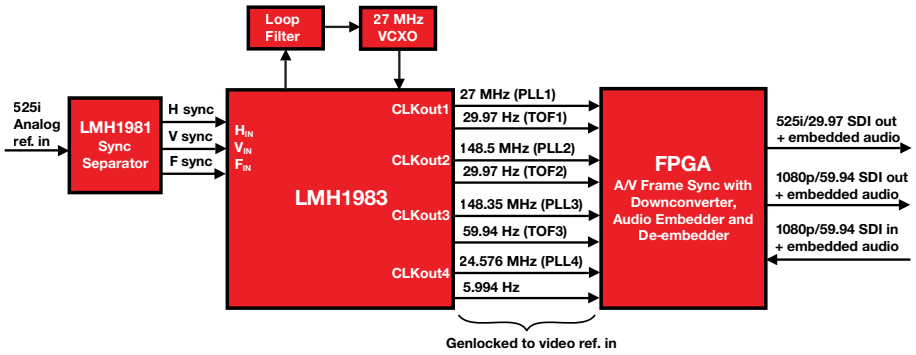
Key Features

- Four PLLs for simultaneous A/V clock generation
- 3.3 V single supply operation
- Flexible PLL bandwidth to optimize jitter performance and lock time
- 3 x 2 Video clock crosspoint

Applications

- Endoscope

The LMH1983 is a highly-integrated programmable audio/video (A/V) clock generator. It can replace multiple PLLs and VCXOs used in applications supporting SMPTE serial digital video (SDI) and digital audio AES3/EBU standards. It offers low-jitter reference clocks for any SDI transmitter to meet stringent output jitter specifications without additional clock cleaning circuits.



LMH1983 typical application.

Endoscopes

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Analog Front Ends				
VSP2582	CCD/CMOS AFE	36MSPS, 12-bits (parallel output), CDS	Low noise, low power, smallest footprint	
VSP2562	CCD/CMOS Analog Front End	36MSPS, 12-bits (parallel output), CDS, w/two 8-bit DACs	Low noise, low power, small footprint, includes two 8-bit DACs to simplify system design	
VSP2566	CCD/CMOS Analog Front End	36MSPS, 16-bits (parallel output), CDS, w/two 8-bit DACs	Higher resolution, low noise, low power, small footprint, includes two 8-bit DACs to simplify system design	
Amplifiers				
LM324	Quadruple Operational Amplifier	Wide supply range 3V to 32V Supply current independent of supply voltage 0.8mA Low input bias 20nA	Excellent performance and reliability	
LM358	Dual Operational Amplifiers	Wide supply range 3V to 32 Supply current independent of supply voltage 0.7mA Low input bias 20nA	Excellent performance and reliability	LMV358
LMH6683	Video Amp	190MHz single supply triple op amps	Provides excellent differential gain and phase combined with output current drive, making it ideal for video processing	
LMH6733	Video Amp	Single-Supply 1GHz low power triple op amps	Offers single/split supply operation, wide gain range, and stability without external compensation at unity gain	
LMH6738	Video Amp	Wideband low distortion triple op amps	Offers single/split supply operation, wide gain range, and stability without external compensation at unity gain	
OPA360	Video Amp	3V video amplifier with low pass filter, internal G=2 and SAG correction in SC70	Designed to work with video processors	OPA361, THS7303
OPA3693	Video Amp	Triple,ultra-wideband, fixed gain, video buffer w/disable	Designed to work with video processors	OPA3832
OPA830	Buffer Amp	250MHz (G = +1) BW, 550V/µs slew rate, 9.2nV/$\sqrt{Hz}$ noise, 3.9mA supply current, single/dual supply	Ideal input buffer stage	OPA2830, OPA847
Data Converters				
THS8135	Video DAC	Triple 10-bit 240MSPS video DAC with tri-level sync and video-compliant (ITU-R.BT601) full-scale range		
THS8200	Video DAC	Triple 10-bit all-format video DAC		
Interface/Video/Clock				
LMH1983	3G/HD/SD Video Clock Generator with Audio Clock	3.3 V single supply operation, 3 x 2 video clock crosspoint	It offers low-jitter reference clocks for any SDI transmitter to meet stringent output jitter specifications without additional clock cleaning circuits.	
LMK03806	High Performance, Ultra Low Jitter Clock Generator with 14 Programmable Outputs	High performance clock generator delivers ultra low RMS jitter < 150 fs and generates multiple clocks from low cost crystal/external clock	Reduces board area and BOM cost by 50% against competing approach	
LMK04100	Precision Clock Jitter Cleaner with Cascaded PLLs	High performance clock jitter cleaner provides jitter cleaning, clock multiplication, and distribution without the need for high-performance VCXO modules & generates 5 ultra low jitter clocks in LVCMOS, LVDS, or LVCPECL formats	Delivers high performance and significantly reduces BOM cost	
LMH6738	Buffer Amp	2.5MHz (G = +1) BW, 550V/µs slew rate, 9.2nV/$\sqrt{Hz}$ noise, 3.9mA supply current, single/dual supply	Ideal input buffer stage	OPA2830, OPA847
SN65LVDS93A	24-bit RGB LVDS Serdes	10MHz-135MHz, BGA and TSSOP; supports 1.8V to 3.3V TTL i/p	Wide frequency range, saves space, no level shifter for 1.8V powered µP	SN75LVDS83B
Processors				
AM3354	Applications Processor	ARM® Cortex-A8, graphics accelerators, touch screen controller	ARM Cortex-A8 performance at power levels of an ARM9	AM3352, AM3356, AM3357, AM3358, AM3359
OMAP3530	Applications Processor	ARM® Cortex-A8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at handheld power levels	OMAP3503, OMAP3515, OMAP3525
TMS320DM355	Digital Media System-on-Chip	64-channel EDMA, 135/216/270MHz ARM926EJ-S clock rate	Encode/decode up to 720p H.264; optimized for power, cost, and efficiency, and is even suitable for three Li-ion AA battery inputs	
TMS320DM365	Digital Media System-on-Chip	64-channel EDMA, 216/270/300MHz ARM926EJ-S clock rate	Encode/decode up to 1080p H.264; high-performance ARM® and video processing capabilities	
TMS320DM368 *Page 140	Digital Media System-on-Chip	HD video processing at 1080p, 432-MHz ARM926EJ-S clock rate	Deliver crystal clear multi-format video at up to 1080p H.264 at 30 fps	
TMS320DM6437	Digital Media Processor	64-channel EDMA, 400/500/600/660/700MHz C64x+™ clock rate	DSP architecture means programmable solution, Benefit from H.264 encode (D1)	
TMS320DM6446	Digital Media System-on-Chip	64-channel EDMA, 513/594MHz C64x+ clock rate	Encode/decode up to 720p MPEG-4, programmable DSP, with GUI and other processing offloaded to the ARM® for greater efficiency and scalability	

To view more system block diagram compatible products, visit **www.ti.com/endoscope**

Endoscopes

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (continued)				
TMS320DM6467	Digital Media System-on-Chip	64-channel EDMA, 594/729/1000MHz C64x+™ clock rate	Encode/decode up to 1080p H.264; high-performance programmable DSP and ARM	
TMS320C6654	Industry's Most Efficient Floating-Point DSPs	850MHz, C66x single core, 2MB L2, 2W	Fixed and floating point DSP, 13.5 GFlops, 27 GMACS	TMS320C6655
TMS320C6747	Industry's Lowest Power Floating-Point DSP	32-/64-bit accuracy, 1.8V to 3.3V I/O supply, low power and rich connectivity peripherals.	Uses three times less power that existing floating-point DSPs	
Microcontrollers				
MSP430F4481	16-Bit Ultra-Low-Power MCU	1.8 V to 3.6 V supply voltage, ultra-low-power consumption, 16-bit RISC architecture	Optimized to achieve extended battery life in portable measurement applications	
LED Drivers				
DRV777	Integrated Motor and Load Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, low output VOL 0.4V Very low input leakage (<20uA)	Easy to use and low noise with Inductive kickback protection	
ULN2003LV	Low Power 3.3V and 5V Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, switching at 8V, low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	ULN2003A, ULN2003V12, ULN2004A, ULN2803A
ULN2003V12	Low Power Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, Switching at 16V low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	
RF Transceivers				
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	
RF Systems-on-Chip				
CC254x	2.4 GHz *Bluetooth*® Low Energy Compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/tablets with extremely low power. Able to run on coin cell battery.	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell.	CC2590/91
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	

To view more system block diagram compatible products, visit **www.ti.com/endoscope**

DLP® Technology

DLP & MEMS

DLP® Discovery™ 4100

For more information, visit **www.ti.com/dlplightcrafter**

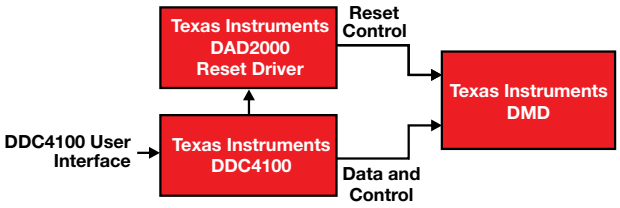
Key Features

- ±12° mirror operation
- Fill factor > 91percent
- Works with visible, near-infrared and ultraviolet light
- DMD: Options include 0.95" 1080p, 0.7" XGA
- DAD2000 power and reset driver
  - Generates reset control of 16 banks of DLP mirrors
- DDC4100 digital controller
  - Provides high-speed (400MHz) LVDS data and control interface and provides mirror reset and timing information to the DAD2000
  - Supports random row addressing

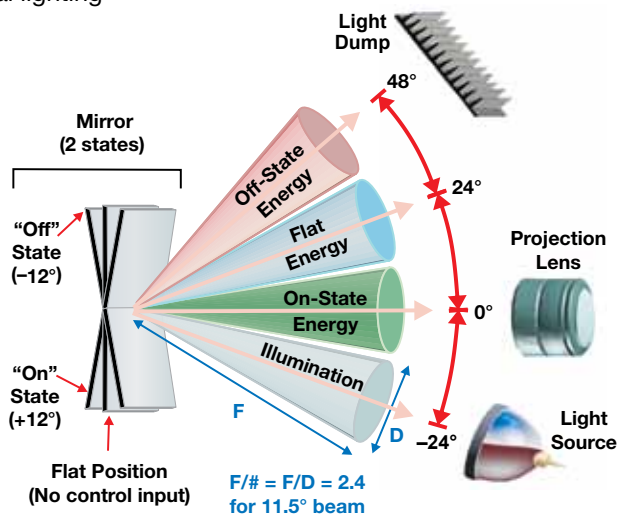
Applications

- Vascular imaging
- Phototherapy
- Chemical analysis
- Micro-array development
- 3-D metrology
- Genomics
- Surgical lighting

DLP® Discovery 4100 is capable of extremely fast switching speeds and offers high resolution performance in Spatial Light Modulation (SLM). Unlike DLP solutions optimized for projection display, the D4100 kit delivers maximum flexibility in formatting and sequencing light patterns and provides developers a robust platform to design industrial, medical and scientific products using the proven reliability of DLP technology. Digital micromirror device (DMD) options include XGA (1024 x 768) and 1080p (1920 x 1080) resolutions that can operate with UV and visible light spectrums. Design flexibility is enabled with interfaces such as: USB 2.0, Avent EXP, 64-bit DDR2 SODIMM DRAM, and many multipurpose I/O.



DLP Discovery 4100 chipset block diagram.



How the light is steered.

DLP Discovery 4100 starter kit.

DLP® Technology

DLP® LightCrafter™
DLPLIGHTCRAFTER

For more information, visit **www.ti.com/dlplightcrafter**

Key Features

- 608 x 684 micromirror array
- 7.6µm micromirror pitch
- Pattern rates up to 4000Hz
- Video display up to WVGA resolution

Applications

- Dental scanning
- Skin measurement
- Augmented reality/Information overlay
- Microscopy
- Portable imaging devices

DLP® LightCrafter™ is a compact, versatile EVM for integrating light into industrial, medical, and scientific applications. Featuring the DLP 0.3 WVGA chipset, the module includes a 20L RGB LED light engine (>50L with additional cooling). Developers can store 100+ patterns onboard and display high-speed sequences (up to 4kHz) with the easy-to-use GUI. DLP LightCrafter has multiple industry standard interfaces including USB, mini-HDMI, and I²C. It also features TI's powerful TMS320DM365 digital media processor running embedded Linux and a MSP430™ microcontroller. A configurable I/O trigger allows for convenient synchronization with cameras, sensors, motors, or other peripheral devices.

DLP® LightCrafter™ EVM.

Module Specifications	
RGB LED light engine	20L continuous light output Capable 50L continuous light output with additional cooling 36cm to 2m focus range
Pattern rates	Up to 4000Hz binary, up to 120Hz 8-bit grayscale
Input video resolutions	Native (608 x 684), WVGA (854 x 480), VGA (640 x 480), QVGA (320 x 240)
Onboard processing	TMS320DM365 digital media processor MSP430 microcontroller Application FPGA
Interfaces	USB for GUI/API commands and pattern download Mini-HDMI for video input I²C for programming DLPC300
Configurable I/O trigger	3.3V output with programmable delay, polarity and pulse width 3.3V input to advance patterns
Miscellaneous	65mm x 116.5mm x 23mm dimensions 128MB NAND flash memory holds 80+ 24-bit patterns

Medical Imaging Toolkit

TI Embedded Processor Software Toolkit for Medical Imaging (STK-MED)

Get more information at: **www.ti.com/medicaltoolkit**
View the “Ultrasound Scan Conversion Demo on OMAP3530” video at: **www.ti.com/stkvideo**

Key Features

- Common medical imaging algorithms optimized for the C64x+™ DSP architecture
- Standard APIs
- Tested, benchmarked, documented library modules

Applications

- Medical imaging
- Medical diagnostic ultrasound
- Optical Coherence Tomography (OCT)

Demos/Open source site

www.ti.com/ultrasounddemo

- Demo of scan conversion module running on OMAP3530
- Open Source of OMAP3530 demo’s software framework

The STK-MED is a collection of several standard medical imaging algorithms optimized for TI’s C64x+ DSP architecture. The algorithms showcase how developers can leverage the C64x+ DSP architecture for efficient performance and power consumption in real-time medical imaging applications such as diagnostic ultrasound and optical coherence tomography (OCT). The goal of the STK-MED is to shorten customer development time by providing highly optimized C64x+ DSP source code of common ultrasound processing blocks.

Medical imaging processing functions in STK-MED

- B-Mode processing
  - Doppler processing (color flow, power estimator, wall filter)
- RF demodulation and decimation
- DAS beamforming
- Scan conversion
- Optimized math utilities
  - 3D rendering
  - Real-time imaging processing for optical coherence tomography (OCT)

Overview

Fitness Overview

The consumer market is focused on personal fitness more than ever before. Heart rate monitors, body worn fitness trackers, and body composition weigh scales are just a few of the options out there for athletes and fitness enthusiasts to measure and monitor personal fitness both during exercise and daily activity. By developing innovative ways to increase integration, lower power consumption, and provide smart connectivity, TI components makes fitness more flexible, affordable, and accessible.

Driven by the fitness electronics user's desire to quickly know their health status -- portable and battery operated fitness devices commonly have goals for extended battery life, high precision and fast response times. Additional requirements may drive the need for more memory to allow for historical profiling, cabled or wireless interfaces for data upload or for access to the sensor. Audio feedback for simple good/not good indication or more complex step-by-step utilization instructions may be required as well. Adding these features without increasing power consumption is a significant challenge.

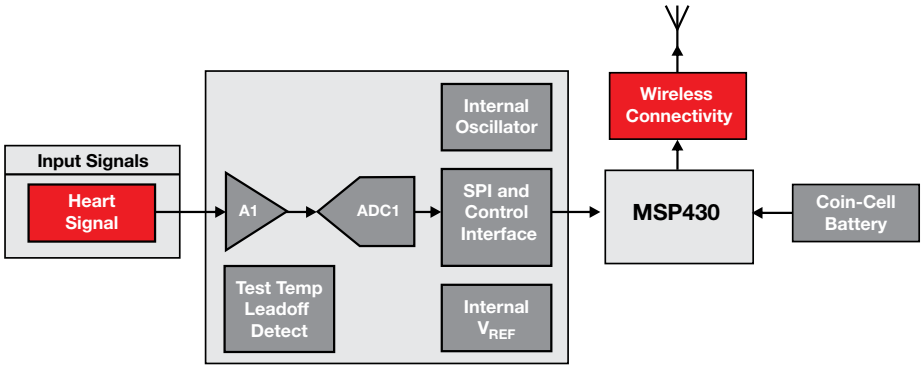
TI features a broad array of comprehensive system block diagrams, selection tables and key design tools to help you accelerate innovation. TI HealthTech's broad portfolio, backed by the resources of the TI global enterprise, is the world's largest producer of analog and embedded processors and the single most experienced source for health-care components in electronic fitness applications.

Heart Rate/Fitness Monitoring Systems

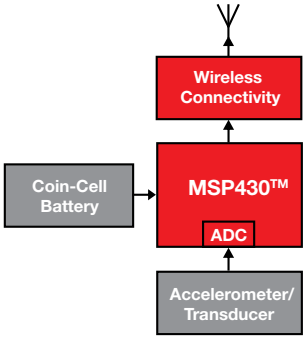
Heart Rate/Fitness Monitors

Fitness monitors measure both a person's amount and rate of exercise (e.g. miles and pace run) as well as effort expended (e.g. through monitoring heart rate). Typically, a wristwatch or wrist-worn display is used for control and providing feedback. Stored data can be downloaded to a computer via USB or a wireless USB dongle. All parts of the system require ultra-low-power embedded controllers and low-power RF for communications. Heart rate monitoring and exercise output monitoring (e.g. running pace sensor or power sensor) require additional signal conditioning.

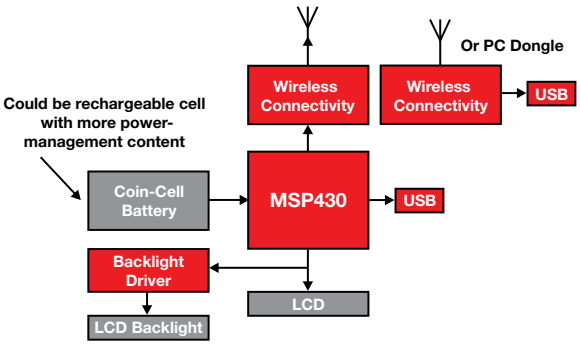
Note: "Heart Rate and EKG Monitor using the MSP430FG439" (slaa280)
www-s.ti.com/sc/techlit/slaa280



Heart rate monitor.



Shoe/footstrike sensor.



Wrist display/watch.

Weight Scale/Body Composition

Integrated Analog Front-End for Weigh-Scale/ Body Comp Measurement

AFE4300

Get samples and datasheets at: **www.ti.com/device/afe4300**

Key Features

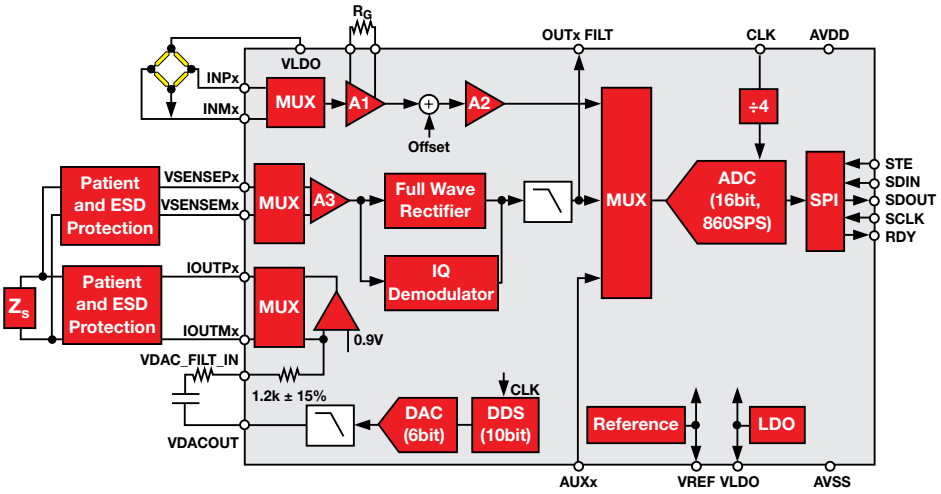
- Fully integrated solution with two signal chains for
  - Weigh scale
  - Body composition
- Provides multiple BCM channels
- Body composition front end options for
  - Tetra-polar measurements
  - Complex impedance measurement
- 2V to 3.6V supply and <1mA supply current

Applications

- Weigh scale – body composition meter
- Body impedance analyzers
- Impedance measurement

The AFE4300 is a low-cost analog front-end incorporating two separate signal chains: one chain for weight measurement and the other for body composition measurement (BCM) analysis. A 16-bit, 860-SPS analog-to-digital converter (ADC) is multiplexed between both chains.

The weight measurement chain includes an instrumentation amplifier (INA) with the gain set by an external resistor, followed by a 6-bit digital-to-analog converter (DAC) for offset correction, and a circuit to drive the external bridge/load cell with a fixed 1.7V for ratiometric measurements.



AFE4300 functional block diagram.

System Support Products

Voltage Level Translation

Applications

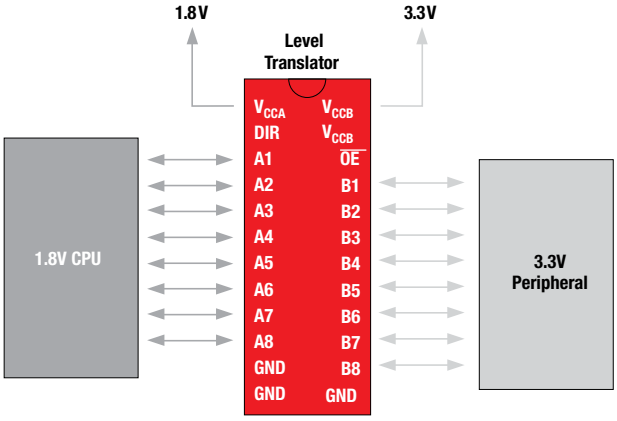
- LCD interface
- Interface devices with different supply voltages

As operating voltage levels in microcontrollers continue to drop, a void that disrupts device interfacing may be created between peripheral devices and processors. TI's translators enable communication between incompatible I/Os with level translation between the 1.2V, 1.5V, 1.8V, 2.5V and 3V nodes. The MSP430™ microcontroller has a 3.6V (max) I/O tolerance, allowing translators to be used to protect the inputs and interface to higher voltage peripherals.

Suggested Components

Component	Description	V_{CC} Range (V)	Power Max I_{CC} (µA)	Smallest Footprint Pins/Packages
SN74AVC1T45*	Single-bit Dual-Supply Bus Transceiver	1.2 to 3.6	10	6/WCSP (NanoStar™)
SN74LVC1T45	Single-bit Dual-Supply Bus Transceiver	1.65 to 5.5	4	6/WCSP (NanoStar)
SN74AVC2T45*	Dual-bit Dual-Supply Transceiver	1.2 to 3.6	10	8/WCSP (NanoStar)
SN74LVC2T45	Dual-bit Dual-Supply Transceiver	1.65 to 5.5	10	8/WCSP (NanoStar)
SN74AUP1T57	Single-Supply Voltage Translator	2.3 to 3.6	0.9	6/WCSP (NanoStar)
SN74AUP1T58	Single-Supply Voltage Translator	2.3 to 3.6	0.9	6/WCSP (NanoStar)
SN74AUP1T97	Single-Supply Voltage Translator	2.3 to 3.6	0.9	6/WCSP (NanoStar)
SN74AUP1T98	Single-Supply Voltage Translator	2.3 to 3.6	0.9	6/WCSP (NanoStar)
PCA9306	Dual Bidirectional I^2C-bus and SMBus Voltage-Level Translator	—	—	8/US

**Bus-hold option available.*



Example application block diagram.

System Support Products

System-Level ESD/EMI Protection

Benefits

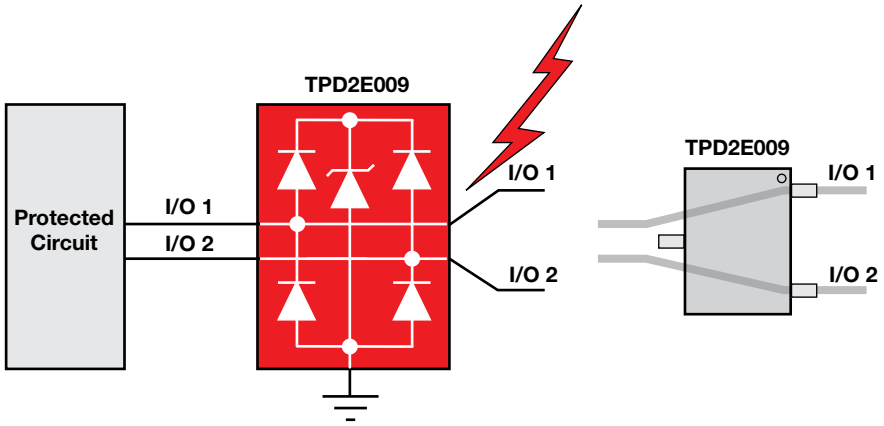
- System-level ESD protection for high-speed interconnects
- Space-saving package and flow-through layout enable glitch-free layout for the high-speed portable applications
- Ultra-low 1nA leakage current enables precision analog measurements like those of glucose meters
- The optional V_{CC} pin allows the device to work as a transient suppressor

Applications

- USB, HDMI, DisplayPort, eSATA, GigEthernet, 1394, Interface
- Analog precision interface

For any external interface connector port, an ESD strike is a constant threat to system reliability. Many low-voltage core chip or system ASICs offer only device-level human-body model (HBM) ESD protection, which does not address system-level ESD. A stand-alone ESD solution is a space- and cost-effective solution to protect the system interconnects from external ESD strikes.

TI's TPDxE series ESD devices provide an IEC-61000-4-2 (Level 4) system-level ESD solution while maintaining signal integrity at the high-speed interfaces. The TPDxF series EMI filter provides immunity against conducted EMI noise while providing system-level ESD protection.



TPD2E009 ESD circuit and board layout.

ESD/EMI Solutions

Device	Number of Channels	V_{DD} (V)	I/O Level (V)	Cap, Resistor	V_{BR} (min) (V)	Package(s)
ESD Solutions						
TPD2E009	2-Channel ESD	0.9 to 5.5/No V_{DD} pin	0 to V_{DD}	0.7pF	6	DRY, DRT, DBZ
TPD4S009	4-Channel ESD	0.9 to 5.5	0 to 5.5	0.8pF	9	DRY, DCK, DBV
TPD4S010	4-Channel ESD	No V_{DD} pin	0 to 5.5	0.8pF	9	QFN
TPD8S009	8-Channel ESD	0.9 to 5.5	0 to 5.5	0.8pF	9	DSM
TPD12S520	12-Channel, HDMI Receiver	0.9 to 5.5	0 to 5.5	0.9pF	9	DBT
TPD12S521	12-Channel, HDMI Driver	0.9 to 5.5	0 to 5.5	0.9pF	9	DBT
TPD4S012	4-Channel ESD with V_{BUS} Clamp	No V_{DD} pin	0 to 5.5	1.0pF, 9pF	7, 20	DRY
TPD2E001	2-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.5pF	11	DRL, DRY, DRS
TPD3E001	3-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.5pF	11	DRL, DRY, DRS
TPD4E001	4-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.5pF	11	DRL, DRS
TPD6E001	6-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.5pF	11	RSE, RSF
TPD6E004	6-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.6pF	6	RSE
TPD4E004	4-Channel ESD	0.9 to 5.5	0 to V_{DD}	1.6pF	6	DRY
TPD4E002	4-Channel ESD	No V_{DD} pin	0 to 6	11pF	6	DRL
EMI Filters						
TPD6F002	6-Channel EMI	0.9 to 5.5	0 to 5.5	17pF, 100Ω, 17pF	6	DSV
TPD6F003	6-Channel EMI	0.9 to 5.5	0 to 5.5	8.5pF, 100Ω, 8.5pF	6	DSV

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Connectivity Solutions

Connectivity plays an important role in clinical, patient monitoring, and consumer medical devices. While wired (USB) connections continue to be used, emphasis is being placed on wireless capabilities that enable connected or networked devices. Portability requirements call for these devices to be small in size, consume minimal power and include the ability to efficiently and accurately feed data to remote sources.

TI has long-time experience providing a wide range of innovative wireless technologies such as ZigBee®, radio frequency identification (RFID), low-power wireless (ISM), *Bluetooth*® technology and WLAN.

USB for Medical Applications

Connectivity for portable medical applications has become critical as data is required to move from medical devices to data hubs such as computers and mobile phones. TI is a promoting member of the Continua Health Alliance aims at solving interoperability issues between connected medical devices. TI offers the first Continua-certified USB platform for Agent Devices.

For more information on the Continua Health Alliance, visit **http://www.continuaalliance.org**

Telehealth

With aging populations, the rise of chronic diseases and increasing health care costs, connected health technologies can help to control the cost of healthcare and enable each of us to maintain a good quality of life.

A telehealth system is designed to transmit vital signs from a personal health device like a heart rate monitor or a blood glucose meter to another location by use of wired or wireless telecommunications technologies to be monitored and analyzed there, e.g. by a health professional.

Industrial, Scientific and Medical (ISM) Band Wireless Offering

TI offers a wide selection of cost-effective ISM bands solutions for both proprietary and standards-based wireless applications that are suitable for medical applications as well. The portfolio includes RF transceivers, RF transmitters and systems-on-chip for applications in the sub-1GHz and 2.4GHz frequency bands.

To choose the right radio for specific applications, designers need to determine at what frequency band to operate. TI's radios operate in either the global 2.4GHz or the sub-1GHz Industrial Scientific Medical (ISM) bands. The 2.4GHz is available for license-free operation in most countries around the world and enables the same solution to be sold in several markets without software/hardware alterations.

The ISM bands devices operating below 1GHz have limitations that vary from region to region, but their strength is their longer range compared to 2.4GHz operating devices when presenting same output power and current consumption. In addition, there is less interference present in the band. Since different sub-1GHz bands are used in different markets, custom solutions become a necessity.

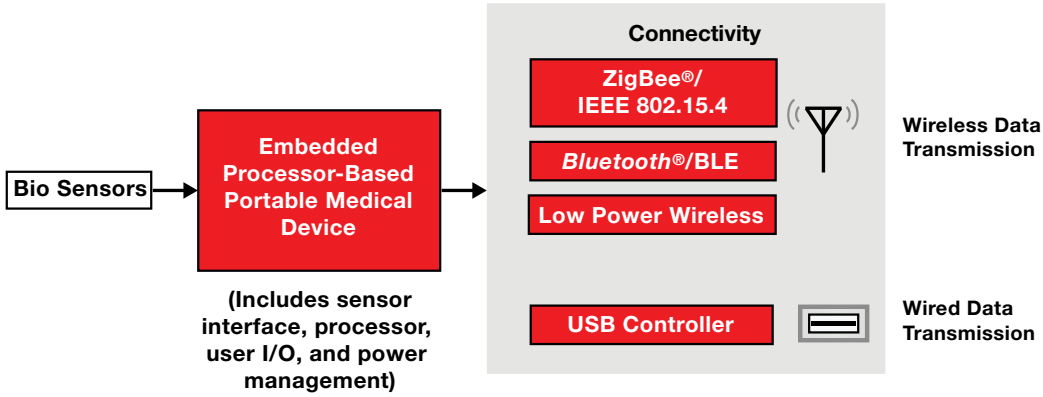
The trade-off between the need for interoperability and the cost of software design and development will, to a large extent, determine the choice of software platform. TI offers a wide range of software to support its different wireless offering. TI's software portfolio ranges from proprietary solutions with a high degree of design freedom and low complexity to fully interoperable ZigBee® solutions.

Connectivity Solutions

Radio Frequency Identification (RFID)
TI's high-frequency RFID product family consists of 13.56MHz high-frequency (HF) transponders and low-power RFID readers that are compliant with ISO/IEC 15693 and ISO/IEC 18000-3 global open standards.

Typical RFID medical applications include blood bag and medical supply tracking, patient/staff authentication, pharmaceutical authentication, medical imaging, product authentication and remote digital healthcare management applications.

TI's Tag-it™ HF-1 family of transponder inlays consists of 13.56MHz HF transponders that are compliant with ISO/IEC 15693 and ISO/IEC 18000-3 global open standards. These products are available in six different antenna shapes with frequency offset for integration into paper, PVC or other substrates manufactured with TI's patented laser-tuning process to provide consistent read performance.



TI has considerable experience designing connectivity solutions for interoperability and coexistence.

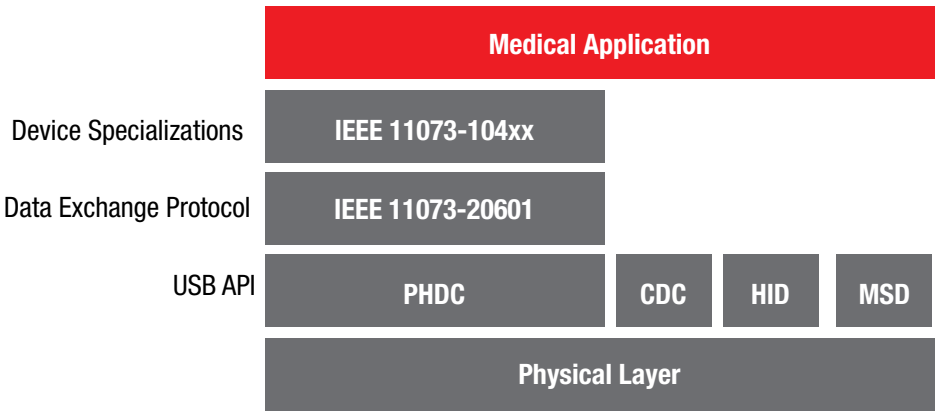
Medical USB Platform

TI offers a Continua-certified USB hardware-software platform that implements the Personal Healthcare Device Class (PHDC) along with IEEE 11073. As personal healthcare devices become more ubiquitous, companies are developing products with connectivity that allow data to be exchanged easily. PHDC (Personal Healthcare Device Class), which is part of the USB standard, is designed for portable medical and wellness devices to be able to send measurements to USB hosts such as personal computers, cell phones, etc. The Continua Health Alliance has released guidelines for interoperability between various types of devices implementing the USB standard. Texas Instruments offers a hardware-software platform that has been certified by the Continua Health Alliance after having passed a rigorous testing procedure. Customers can use the software stacks of this platform to reduce development time for devices that will comply with the medical industry standards such as the Continua Health Alliance. These stacks are available for use on TI's industry-leading, ultra-low-power MSP430™ MCUs.

For more information on the medical USB platform, visit **http://www.ti.com/usbplatform.**

For more information on the Continua Health Alliance, visit **http://www.continuaalliance.org.**

Continua® HEALTH ALLIANCE

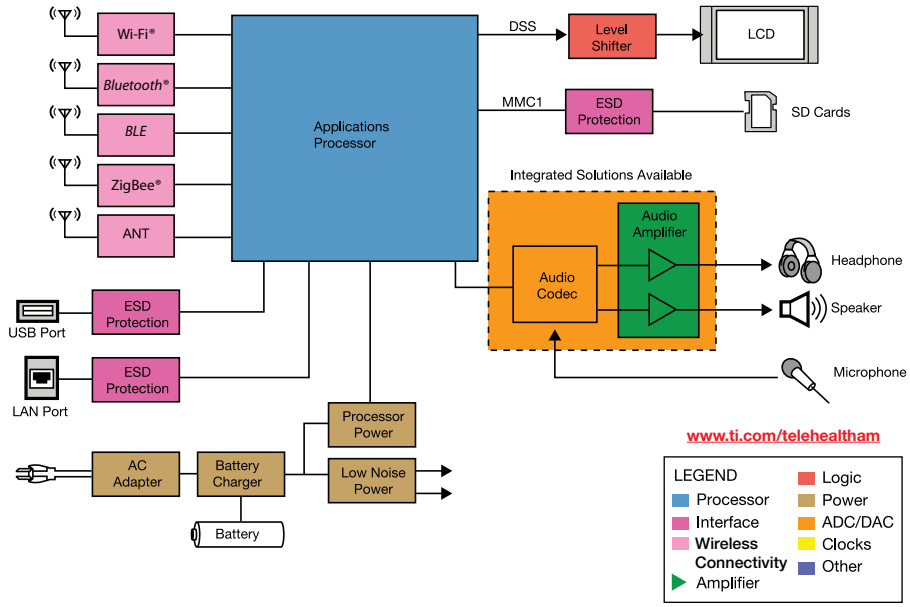


Telehealth Aggregator Manager

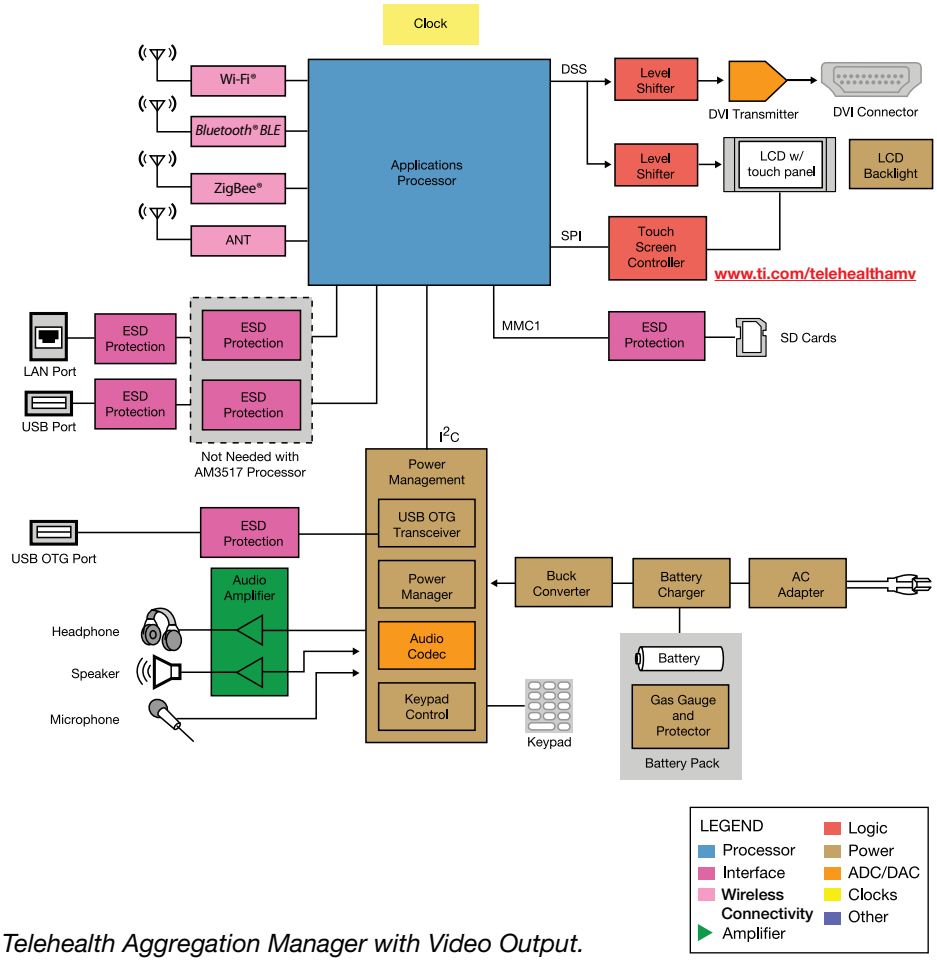
TI products that fit your Telehealth Aggregation Manager design

With aging populations, increasing incidence of chronic diseases, and the need to control health care costs, connected health technologies are becoming increasingly important. The Telehealth/Telemedicine Aggregation Manager is an essential device in the connected health system enabling personal health devices to log data in a remote EHR (Electronic Health Record) for family and clinical review. Higher end Aggregation Managers can also support multimedia functions. Get your design started now with complete solutions from TI for a dedicated low power Aggregation Manager with or without video output.

- Visit **www.ti.com/telehealth** for more information
- View our Continua white paper: **http://www.ti.com/litv/pdf/swpy026**
- View interactive system block diagrams:
  - Telehealth aggregation manger at **www.ti.com/telehealtham**
  - Telehealth aggregation manager with video output at **www.ti.com/telehealthamv**



Telehealth Aggregation Manager



Telehealth Aggregation Manager with Video Output.

Wireless Connectivity Solutions

Wi-Fi® Module

SimpleLink™ Wi-Fi® CC3000 Module

Get samples and datasheets at: **www.ti.com/sc/device/cc3000**

Key Features

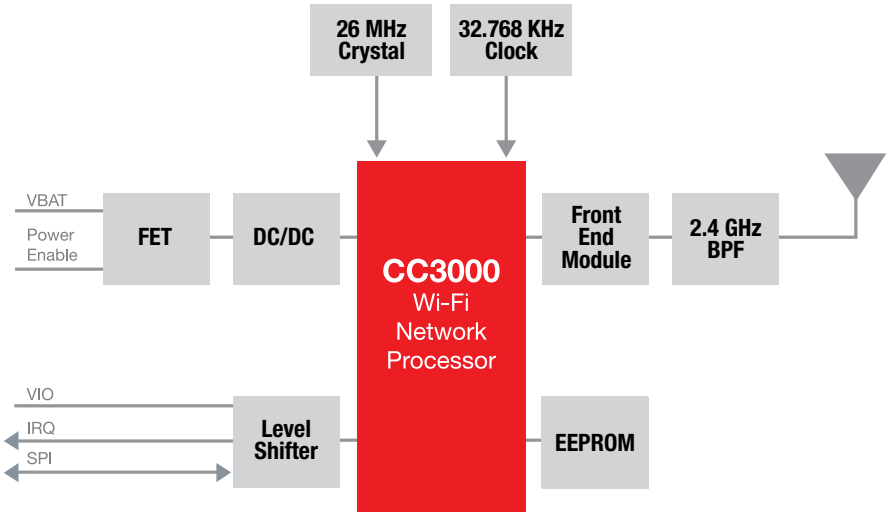
- Wireless Network Processor
  - IEEE 802.11 b/g
  - Embedded IPv4 TCP/IP Stack
- Best-in-class Radio Performance
  - Tx Power: +18dBm, 11Mbps
  - Rx Sensitivity: –88dBm, 11Mbps
- Single Power Supply 2.7V to 4.8V
- Pair with low MIPS, low cost MCU's with compact memory footprint
- FCC/IC/CE certified reference design with dipole or chip antenna
- Small form factor module
  - 16.3mm x 13.5mm x 2mm
- Temperature range –20C to +70C
- SmartConfig™ technology enables simple Wi-Fi® configuration using a smartphone, tablet or PC
- Proven Wi-Fi® interoperability based on TI's 7th generation Wi-Fi® solution
- Complete platform solution including user and posting guides, API guide, sample applications and support community

Development Tools and Software

- Evaluation Module (EM) to connect to a variarty of development boards including MSP430™, Tiva™ C Series, C2000™, and C55x
- Boosterpack for TI MCU LaunchPads available
- Integrated Development Kit: CC3000FRAMEMK-L and CC3000FRAMEMK-M available today with MSP-EXP430FR5739 included
- Stand-alone EM board available through distributors such as Arrow, Avnet, Digi-Key and Mouser
- Sample applications available: **www.ti.com/tool/cc3000-platform**

TI continues to advance Wi-Fi® technology solutions for the Internet of Things with the enhancement of the self-contained SimpleLink™ Wi-Fi® CC3000 module. CC3000 features enhanced software designed to dramatically simplify design and development while advancing the user experience. The new SimpleLink CC3000 is an ideal solution for developers of health and fitness, home automation, smart metering, security, and safety applications.

The CC3000 is provided as a certified module by TI to reduce development time, lower manufacturing costs, save board space and minimize RF expertise required. Additionally, it is provided as a complete platform solution including software drivers, sample applications, API guide, user documentation and a world-class support community.



CC3000 module diagram.

Wireless Connectivity Solutions

Bluetooth® Solutions

CC2560 (*Bluetooth*®) and CC2564 (*Bluetooth*® + *Bluetooth*® low energy or ANT™) Module

Get more information at: **www.ti.com/cc256xwiki**

Key Features

- Communicates with *Bluetooth* low energy or ANT single mode devices
- Best-in-class *Bluetooth*® RF performance (Tx Power, Rx sensitivity)
- Operating temperature range: –40°C to +85°C
- Supply voltage range: 0.5V to 4.8V
- Pre-integrated *Bluetooth*® stack for with TI's ultra-low-power MSP430 and Tiva™ C Series ARM® MCUs
- Supports extended range Tx power with 10dBm typical output
- Low power scan method and inquiry scans at 1/3rd normal power
- UART rates up to 4Mbps
- Receive sensitivity: –95dBm

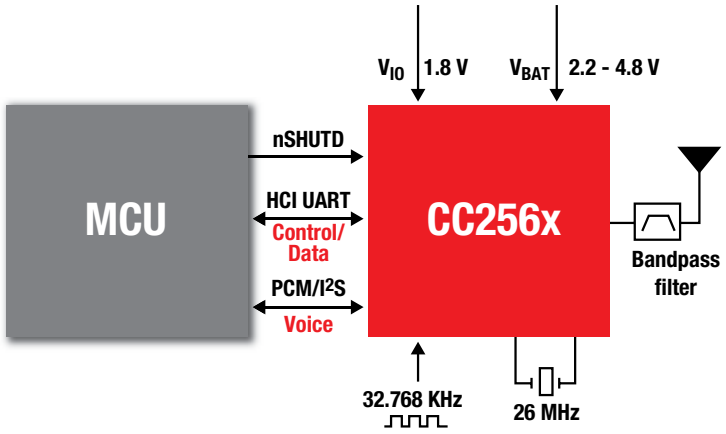
Benefits

- Best-in-class link budget extends application range
- Simplified hardware and software development
- Reduced development time and costs
- Enables simultaneous operations of *Bluetooth*® with *Bluetooth*® low energy or ANT
- 2x Range for *Bluetooth*® low energy applications

Development Tools

- CC256x *Bluetooth*® Development Platform with PAN1323EMK (works with MSP430 boards sold separately – MSP430F5438/5529)
- EZ430-RF256x *Bluetooth*® Evaluation Tool
- Tiva C Series + CC2560 *Bluetooth*® Development Platform- DK-EMZ-2560B
- ANT + *Bluetooth*® Health and Fitness Aggregator – CC2567PAN1327ANTBT

TI now provides *Bluetooth*® v4.0 technology through easy-to-integrate CC2560 (*Bluetooth*®) and CC2564 (*Bluetooth*® + *Bluetooth*® low energy or ANT™) devices in QFN packages through its distribution partners. With the QFN device, TI also provides and supports a reference design that can be copied and pasted into end applications. The same technology is also provided in pre-certified modules from partners such as Panasonic, LSR, Murata and Stonestreet One/BlueRadios, Inc. TI also provides a royalty-free *Bluetooth*® and *Bluetooth*® low energy stack and profiles for TI's MSP430™ and Tiva C Series microcontrollers. Customers have flexibility with partner, Stonestreet One, to customize the stack for different configurations and platforms.



TI's CC2560 (Bluetooth®) and Dual-Mode CC2564 (Bluetooth® + Bluetooth® low energy or ANT) system diagram.

Wireless Connectivity Solutions

Single-Mode Bluetooth® Low Energy System-on-Chip
CC2540

Get samples, evaluation modules and app reports at: **www.ti.com/sc/device/CC2540**

See also: **www.ti.com/product/tps62730**

Key Features

- True one-chip single mode *Bluetooth*® low energy solution
- Optimized RF performance including Tx/Rx power and selectivity
- Extensive peripheral set including USB, DMA, GPIO, USARTs, ADC, timers
- Flexible low power modes to maximize system lifetime when battery powered

Benefits

- Versatile feature-rich device allows lowest cost system when integrating application and stack on single chip
- RF performance maximizes communication range while simultaneously minimizing the effect of interference sources
- Supports range of applications and reduces BOM cost through all-in-one SoC solution
- Ultra low average-power consumption in low-duty cycle systems

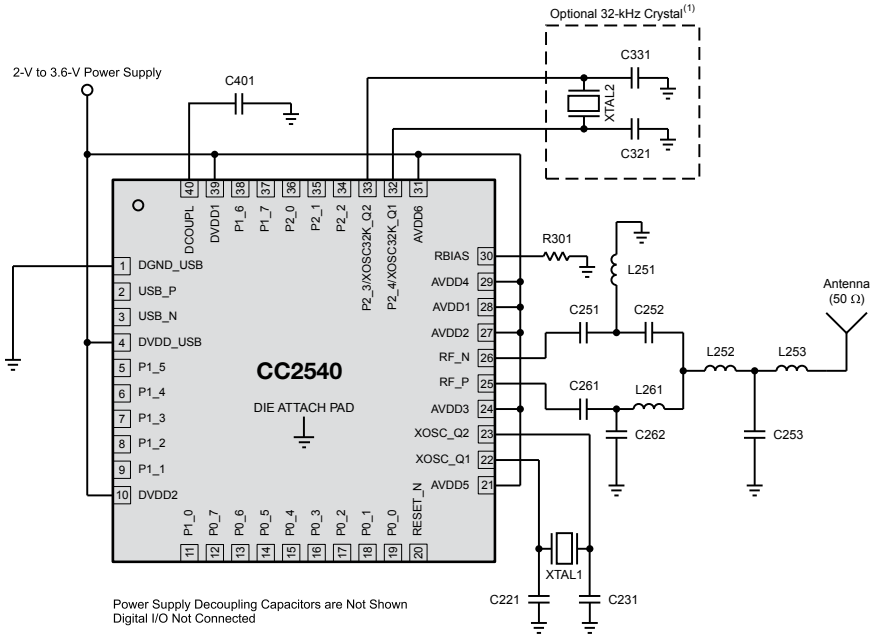
Applications

- Mobile/laptop accessories
- Sports and fitness
- Consumer health and medical
- Proximity

Development Tools and Software

- Single mode *Bluetooth*® low energy compliant software stack
- CC2540DK-MINI Development Kit for quick product development
- *Bluetooth*® low energy packet sniffer
- Application profiles, sample applications, documentation and more

The CC2540 is a cost-effective, low- power, true System-on-Chip (SoC) solution for single-mode *Bluetooth*® low energy applications, including mobile accessories, sports and fitness, consumer health, sensors and actuators, remote controls, HID, proximity, and more. The CC2540 combines a 1Mbps GFSK RF transceiver, offering superior range over the competition with a peripheral rich 8051 MCU core. This highly integrated and low cost SoC, coupled with TI's *Bluetooth*® low energy stack, offers a true one-chip integrated solution.



CC2540 application circuit.

General Characteristics

Parameter	Min	Typ	Max	Unit
Frequency range	2402		2480	MHz
Data rate	—	1000	—	kBaud
Operating voltage	2	—	3.6	V
Operating temperature	–40	—	85	°C
Output power	–20	—	4	dBm
RX mode				
Receiver sensitivity	—	–93	—	dBm
Adjacent channel rejection, +1MHz	—	5	—	dB
Adjacent channel rejection, –1MHz	—	5	—	dB
Alternate channel rejection, +2MHz	—	30	—	dB
Alternate channel rejection, –2MHz	—	30	—	dB
Current consumption				
Current consumption, RX	—	19.6	—	mA
Current consumption, TX, +4dBm	—	31.6	—	mA
Current consumption, TX, 0 dBm	—	27	—	mA
Current consumption, power down	—	0.4	—	µA

Wireless Connectivity Solutions

Single-Mode Bluetooth® Low Energy System-on-Chip

CC2541

Get samples, evaluation modules and app reports at: **www.ti.com/cc2541**

Key Features

- True one-chip single mode *Bluetooth*® low energy solution
- Optimized RF performance including Tx/Rx power and selectivity
- Extensive peripheral set including I²C, DMA, GPIO, USARTs, ADC, timers
- Flexible low power modes to maximize system lifetime when battery powered

Benefits

- Versatile feature-rich device allows lowest cost system when integrating application and stack on single chip
- RF performance maximizes communication range while simultaneously minimizing the effect of interference sources
- Supports range of applications and reduces BOM cost through all-in-one SoC solution
- Ultra low average-power consumption in low-duty cycle systems

Applications

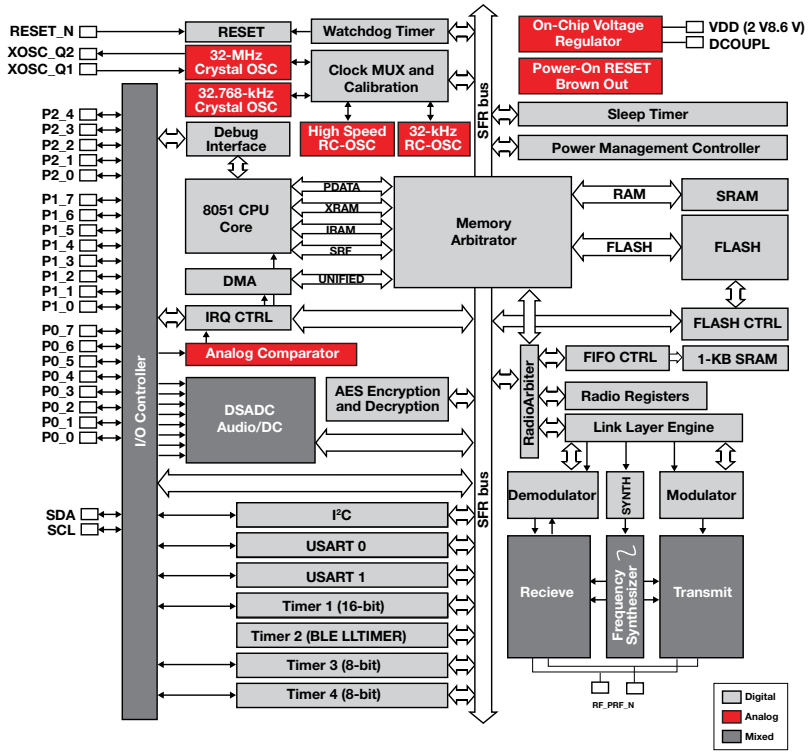
- Mobile/laptop accessories
- Sports and fitness
- Consumer health and medical
- Proximity

Development Tools and Software

- Single mode *Bluetooth*® low energy compliant software stack
- CC2541EMK Evaluation Module Kit for quick product development
- CC2541DK-MINI Development Kit for quick product development
- CC2540DK Development Kit for advance prototyping
- *Bluetooth*® low energy packet sniffer
- Application profiles, sample applications, documentation and more

The CC2541 is a power-optimized true system-on-chip (SoC) solution for both low energy and proprietary 2.4-GHz applications. It enables robust network nodes to be built with low total bill-of-material costs. The CC2541 combines the excellent performance of a leading RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful supporting features and peripherals. The CC2541 is highly suited for systems where ultralow power consumption is required. This is specified by various operating modes. Short transition times between operating modes further enable low power consumption.

The CC2541 is pin-compatible with the CC2540 in the 6-mm × 6-mm QFN40 package, if the USB is not used on the CC2540 and the I²C/extra I/O is not used on the CC2541.



General Characteristics

Parameter	Min	Typ	Max	Unit
Frequency range	2402		2480	MHz
Data rate	—	1000	—	kBaud
Operating voltage	2	—	3.6	V
Operating temperature	–40	—	85	°C
Output power	–20	—	0	dBm
RX mode				
Receiver sensitivity	—	–93	—	dBm
Current consumption				
Current consumption, RX	—	17.9	—	mA
Current consumption, TX, 0dBm	—	18.2	—	mA
Current consumption, power down	—	0.4	—	µA

Wireless Connectivity Solutions

Ultra-High Performance RF Narrowband Transceiver

CC1125

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/cc1125**

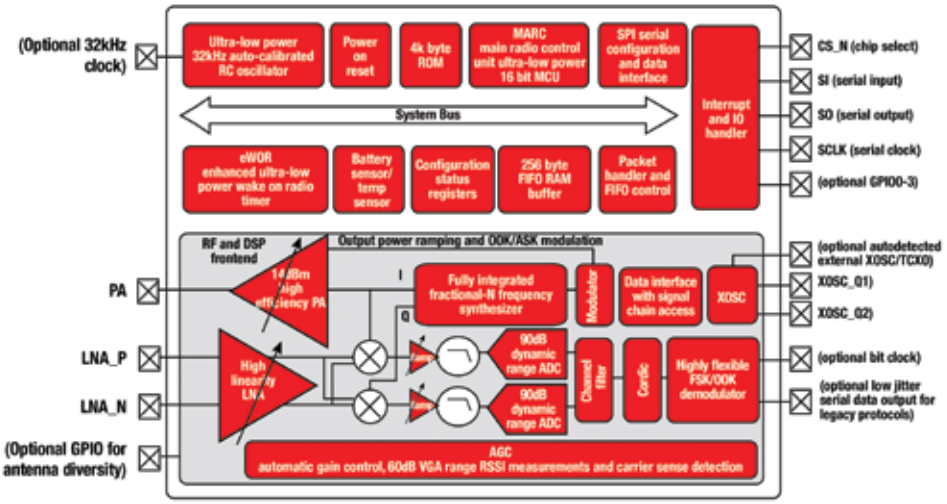
Key Features

- High performance single chip transceiver
- Suitable for systems targeting ETSI cat. 1 compliance
- High spectral efficiency (9.6kbps in 12.5kHz channel in compliance with FCC narrowbanding mandate)
- Wide supply voltage range and low current consumption
- Programmable output power up to +16dBm with 0.4dB step size
- Automatic output power ramping

Applications

- Wireless healthcare applications
- Social alarms
- Wireless alarm and security systems
- Industrial monitoring and control
- Wireless sensor networks and active RFID

The CC1125 sub-1 GHz RF transceiver is the industry's first single-chip solution suitable for wireless social alarms and ultra narrowband applications, targeting ETSI EN 300 220 category 1 (ETSI Cat.1) compliance for the European 869MHz band. To guarantee a highly reliable wireless connection, the ETSI Cat.1 requires conformity to one of Europe's strictest radio frequency regulations. Up till now this performance has only been available through the use of costly and space demanding discrete designs. The high RF performance and narrow channel spacing also benefit applications that require exceptional RF range and robustness.



CC1125 functional block diagram.

RFID and Tag-it™

Radio Frequency Identification (RFID)

TI's high-frequency RFID product family consists of 13.56MHz high-frequency (HF) transponders and low-power RFID readers that are compliant with ISO/IEC 15693 and ISO/IEC 18000-3 global open standards. Typical RFID implementations include asset tracking, access control, blood bag tracking, medical supply tracking, patient/staff authentication, pharmaceutical authentication, medical imaging, product authentication, remote digital healthcare management applications and many non-medical related applications.

Tag-it HF-I Transponder Inlays

TI's Tag-it HF-I family of transponder inlays consists of 13.56MHz HF transponders that are compliant with ISO/IEC 15693 and ISO/IEC 18000-3 global open standards. These products are available in six different antenna shapes with frequency offset for integration into paper, PVC or other substrates manufactured with TI's patented laser-tuning process to provide consistent read performance. Prior to delivery, the transponders undergo complete functional and parametric testing to provide the high quality customers have come to expect.

Tag-it HF-I Family

Product Specifications

- Supported standards: ISO/IEC 15693-2, -3; ISO/IEC 18000-3
- Recommended operating frequency: 13.56MHz
- Factory programmed read-only numbers: 64-bit
- Typical programming cycles (at +25°C): 100,000
- Data retention time (at +55°C): >10 years

Key Features

- User and factory lock per block
- Application Family Identifier (AFI)

Standard

- 256-bit user memory, 8 x 32-bit
- FastSID

Pro

- 256-bit user memory, 8 x 32-bit
- Password-protected write command
- Command to disable IC functionality
- FastSID

Plus

- 2Kbit user memory, 64 x 32 6-bit
- Data Storage Format Identifier (DSFID)
- Combined inventory read block

Tag-it™ HF-I Plus Inlay Shapes

Part Number	RI-I11-112A-03	RI-I11-112B-03	RI-I02-112A-03	RI-I02-112B-03	RI-I03-112A-03	RI-I15-112B-03	RI-I16-112A-03	RI-I17-112A-03
Available Memory	2K bits organized in 64 x 32-bit blocks							
Antenna Size (mm)	45 x 45	45 x 45	45 x 76	45 x 76	22.5 x 38	34 x 65	θ 24.2	θ 32.5
Foil Pitch (mm)	50.8 + 0.1/ –0.4 (2 in)	50.8 + 0.1/ –0.4 (2 in)	96 + 0.1/ –0.4 (~3.78 in)	96 + 0.1/ –0.4 (~3.78 in)	58 +0.1/ –0.4 (~1.89 in)	101.6 +0.1/ –0.4 (4 in)	50.8 +0.1/ –0.4 (2 in)	50.8 +0.1/ –0.4 (2 in)
Frequency Offset for Lamination Material	Paper	PVC	Paper	PVC	Paper/PVC	PVC	Paper/PVC	Paper/PVC
Delivery	Single tape row with 48mm foil width wound on cardboard reel							

Tag-it™ HF-I Pro Transponder Inlays

Part Number	RI-I11-114A-S1	RI-I11-114B-S1	RI-I02-114A-S1	RI-I02-114B-S1	RI-I03-114-S1	RI-I16-114-S1	RI-I17-114-S1
Available Memory	256 bits organized in 8 x 32-bit blocks						
Foil Width (mm)	48mm ±0.5mm						
Antenna Size (mm)	45 x 45	45 x 45	45 x 76	45 x 76	22.5 x 38	θ 24.2	θ 32.5
Foil Pitch (mm)	50.8 +0.1/ –0.4 (2 in)	50.8 +0.1/ –0.4 (2 in)	96 +0.1/ –0.4 (~3.78 in)	96 +0.1/ –0.4 (~3.78 in)	48 +0.1/ –0.4 (~1.89 in)	50.8 +0.1/ –0.4 (2 in)	50.8 +0.1/ –0.4 (2 in)
Frequency Offset for Lamination Material	Paper	PVC	Paper	PVC	Paper/PVC	Paper/PVC	Paper/PVC
Delivery	Single row tape wound on cardboard reel						

Tag-it™ HF-I Standard Transponder Inlays

Part Number	RI-I11-114A-01	RI-I11-114B-01	RI-I02-114A-01	RI-I02-114B-01	RI-I03-114-01	RI-I16-114-01	RI-I17-114-01
Available Memory	256 bits organized in 8 x 32-bit blocks						
Foil Width (mm)	48mm ±0.5mm						
Antenna Size (mm)	45 x 45	45 x 45	45 x 76	45 x 76	22.5 x 38	θ 24.2	θ 32.5
Foil Pitch (mm)	50.8 +0.1/ –0.4 (2 in)	50.8 +0.1/ –0.4 (2 in)	96 +0.1/ –0.4 (~3.78 in)	96 +0.1/ –0.4 (~3.78 in)	48 +0.1/ –0.4 (~1.89 in)	50.8 +0.1/ –0.4 (2 in)	50.8 +0.1/ –0.4 (2 in)
Frequency Offset for Lamination Material	Paper	PVC	Paper	PVC	Paper/PVC	Paper/PVC	Paper/PVC
Delivery	Single row tape wound on cardboard reel						

RFID and Tag-it™

Multi-Protocol Fully Integrated 13.56MHz RFID/NFC Transceiver IC

TRF7970A

Get samples and datasheets at: **www.ti.com/sc/device/trf7970A**

Key Features

- NFCIP-1, NFCIP-2
- Peer-to-peer, card emulation, Reader/writer functionality
- ISO14443A, ISO14443B, FeliCa, ISO15693
- Supply voltage range: 2.7V to 5.5V
- Parallel or SPI interface
- Integrated data framing, CRC and/or parity checking
- Integrated voltage regulators for MCU supply (20mA)
- Clock output for MCU
- Selectable receive gain with AGC
- Antenna driver using OOK or ASK modulation
- Programmable output power, 100mW and 200mW
- RF field detector with programmable wake-up levels
- Eight user selectable power modes
- Power down 1µA
- NFC software library available

The TRF7970A is an integrated analog front end and data-framing device for a 13.56-MHz RFID/near field communication system. Built-in programming options make it suitable for a wide range of applications for proximity and vicinity identification systems.

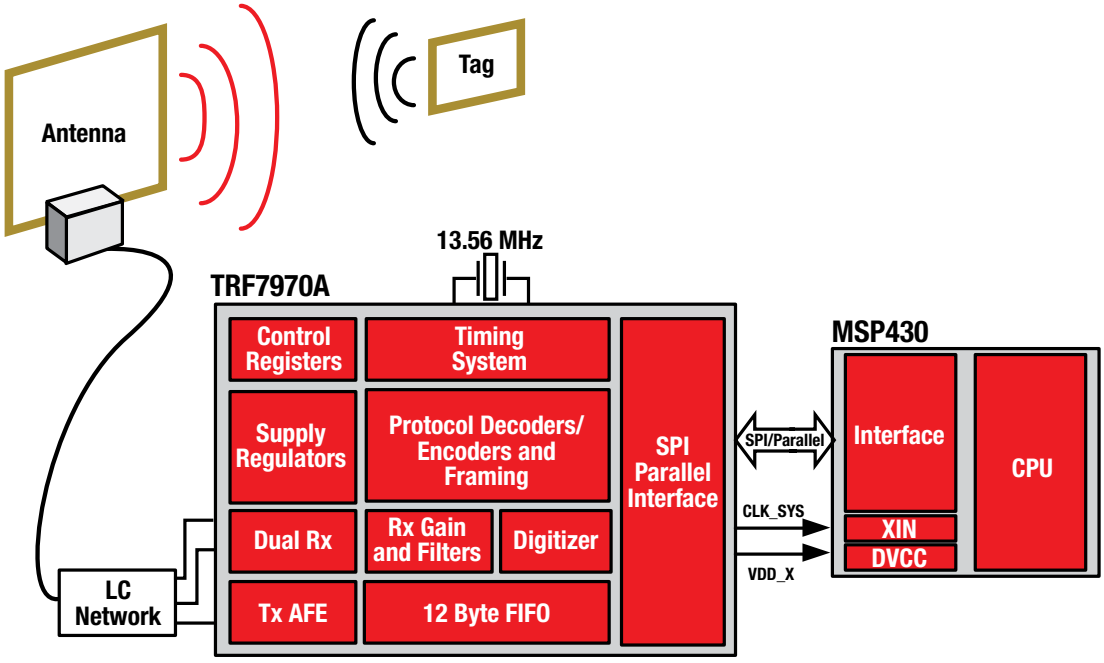
It can perform in one of three modes: RFID/NFC reader, NFC peer, or in card emulation mode. Built-in user-configurable programming options make it suitable for a wide range of applications.

Benefits

- High level of integration enables reduction in system size and cost
- Ultra-low-power capability extends battery life
- High level of flexibility and configurability
- TRF7970A supports NFC tag type 1, 2, 3, and 4 operations, so this architecture enables the customer to build a complete cost-effective yet high-performance multi-protocol 13.56-MHz RFID/NFC system together with a low-cost microcontroller, MSP430™

Applications

- Medical
- Patient and staff authentication
- Pharmaceutical authentication
- Product authentication and calibration
- Remote digital healthcare management
- RFID reader/tag
- Access control/digital door-lock
- POS contactless payment
- Secure pairing of *Bluetooth*®/WiFi



Functional block diagram.

Wired Solutions

USB-to-Serial Bridge

TUSB3410

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/tusb3410**

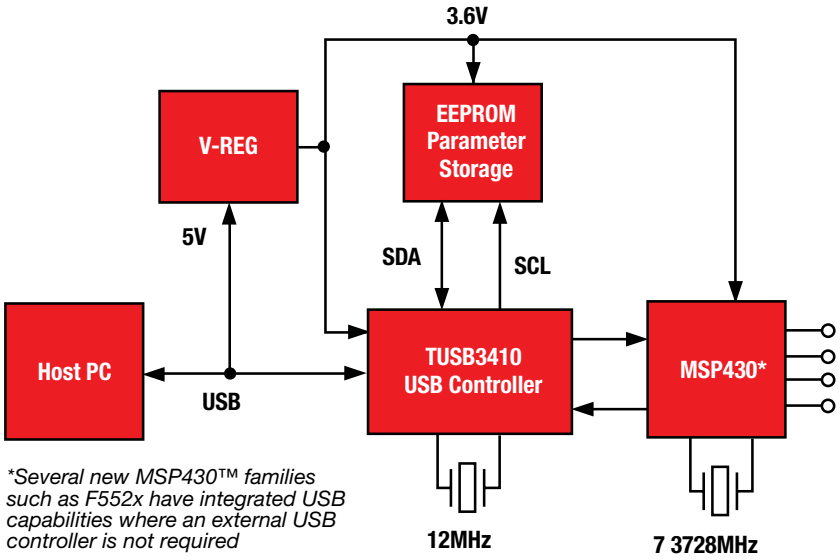
Key Features

- USB full-speed (12Mbps) compliant
- Integrated 8052 microcontroller with 16K bytes of RAM that can be loaded from the host or external memory via an I^2C bus
- Integrated, enhanced UART features include:
  - Programmable software/hardware flow control
  - Automatic RS-485 bus transceiver control, with and without echo
  - Software-selectable baud rate from 50 to 921.6K baud
  - Built-in, 2-channel DMA controller for USB/UART bulk I/O
- TUSB3410UARTPDK product development kit can jump-start USB-to-serial development

Applications

- Handheld meters
- Health metrics/monitors
- Legacy-free PC COM port replacement

TUSB3410 and TUSBWINVCP software provides an easy way to move serial-based legacy devices to a fast, flexible USB interface by bridging a USB port and an enhanced UART serial port. The TUSB3410 contains all of the logic needed to communicate with the host computer using the USB bus. The TUSBWINVCP software package enables the TUSB3410 to act as a virtual COM port and appear as legacy COM ports on the back of older model computers. This enables the use of existing devices and application software without making any changes.



TUSB3410/MSP430™ implementation block diagram.

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC1120	Sub-1GHz RF Transceiver	Industry leading RF blocking and selectivity: 65dB adjacent channel rejection at 12.5kHz offset 90dB blocking. High output power (up to +16dBm) and excellent sensitivity (–123dBm @1.2kbps). WaveMatch; Advanced DSP sync detector with high sensitivity and strong noise immunity.	The most robust RF transceiver on the market. Reliable communication in presence of RF interference. Up to 139dB RF link budget. More reliable links, no false sync detects in noise. Enables RF sniff mode with <3mA current consumption.	
CC2520	2.4GHz ZigBee®/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temperature range; AES-128 security module	Reliable RF link with interference present; 400m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
CC2560	*Bluetooth*® v2.1 + EDR (Enhanced Data Rate)	Fully qualified *Bluetooth*® v2.1 + EDR, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva™ C Series ARM® platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs	
CC2564	*Bluetooth*® v4.0	Fully qualified *Bluetooth*® v4.0 with dual mode capability, +10dBm Tx power with transmit power control, –93dBm received sensitivity, support for *Bluetooth*® power saving modes (sniff, hold), hardware and software pre-integration with TI's MSP430 and Tiva C Series platforms, FCC, CE and IC certified module options, broad market offering with extensive documentation, sample software, and support forums, ability to connect to existing mobile devices without BLE and some newer devices with BLE	Supports replacement of serial cables for personal area networks, high throughput, robust connection with extended range, extended battery life and power efficiency reduced development time and costs, flexibility to use various MCUs and connect to any type of existing device	CC2530
RF Systems-on-Chip				
CC2530/31	Second Gen. System-on-Chip Solution for 2.4GHz IEEE 802.15.4/RF4CE/ ZigBee®	Excellent RX sensitivity, low power, easy to use development tools	RF design system-on-chip for quick time to market. Provides a robust and complete ZigBee® USB dongle or firmware-upgradable network node.	CC2590/91
CC254x	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Best-in-class System-on-chip *Bluetooth*® low energy solution enabling devices to connect to smartphone/ tablets with extremely low power. Able to run on coin cell battery	System-on-chip for quick time to market. Provides a robust and complete *Bluetooth*® low energy stack enabling extremely long battery life and ability to run on a single coin-cell	CC2590/91
RF Network Processor				
CC3000	SimpleLink™ Wi-Fi® CC3000 Module	One step configuration with SmartConfig Technology, easy to use Wi-Fi® solution with compact code size to be used with microcontrollers, best-in-class link budget, precertified FCC/IC/CE module, small form factor module and $9.99 price point for 1k units, proven Wi-Fi® interoperability, broad market offering with extensive documentation, sample software, and support forums	Universal IP connectivity can be enabled on low memory, low-cost, low-power microcontroller systems, has low certification cost and is easy to use for development	
RF NFCs				
TRF7970A	Multi-Protocol Fully Integrated 13.56MHz RFID/NFC Transceiver IC	NFCIP-1, NFCIP-2. Peer-to-peer, card emulation, reader/writer functionality ISO14443A, ISO14443B, FeliCa, ISO15693 NFC software library available.	High level of integration enables reduction in system size and cost ultra low power capability extends battery life high level of flexibility and configurability	TRF7960

To view more system block diagram compatible products, visit ***www.ti.com/healthtech***

Power Management

0.7V_{IN} Boost Converter with 5µA I_Q

TPS61220

Get samples and datasheets at: **www.ti.com/sc/device/TPS61220**

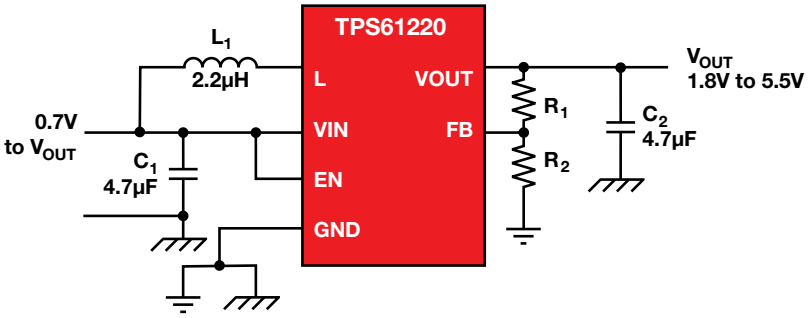
Key Features

- Extended battery run time due to extreme low quiescent current of <5µA
- Ideal for low-current applications due to low switch-current limit
- Works well with low-power microcontrollers like TI's MSP430™ family
- Switching frequency: 2MHz
- Packaging: SC-70

Applications

- Microcontroller power supply
- Any portable application

TI's TPS6122x boost converters manage the power conversion to applications powered by a single-cell, two-cell, or three-cell alkaline, NiCd or NiMH, or one-cell Li-Ion or Li-Polymer battery. The devices provide an output current up to 50mA at a 5V output while using a single-cell Li-Ion or Li-Polymer battery, and discharge it down to 2.5V. The TPS6122x family is based on a hysteretic, fixed off-time controller using synchronous rectification to obtain maximum efficiency at the lowest possible quiescent current level. Maximum input current is limited to a value of 250mA. Output voltage can be programmed by an external resistor divider or can be fixed internally on the chip. The TPS6122x converters are available in a 6-pin, 2mm x 2mm SC-70 package.



TPS61220 boost converter with low I_Q.

Power Management

White LED Driver with Digital and PWM Brightness Control

TPS61160, TPS61161

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/tps61160** or **www.ti.com/sc/device/tps61161**

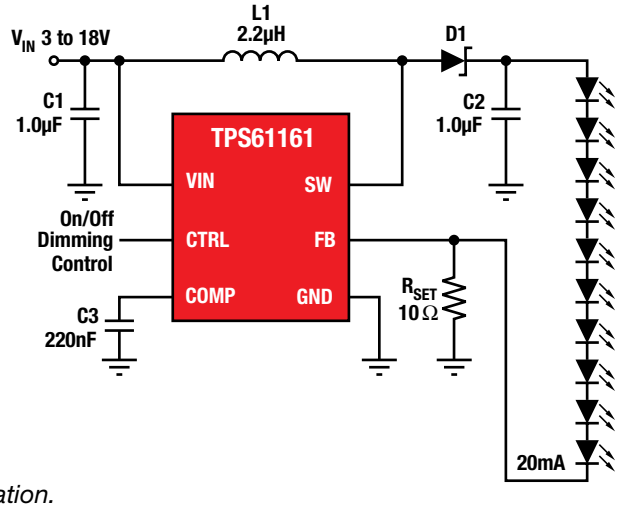
Key Features

- 2.7 to 18V input-voltage range
- 26V open LED protection for 6 LEDs (TPS61160)
- 38V open LED protection for 10 LEDs (TPS61161)
- 0.7A switch current-limit protection
- 600kHz switching frequency
- 200mV ref voltage with 2% accuracy
- EasyScale™ one-wire dimming interface
- PWM brightness control (5 to 100kHz)
- Built-in soft start
- Packaging: 2mm x 2mm x 0.8mm QFN-6

Applications

- 2.5 to 4.0" displays
- PDAs, cell phones, handheld computers
- GPS receivers
- General white LED backlighting for media form-factor displays

With a 40-V rated integrated switch FET, the TPS61160 and TPS61161 are boost converters that drive up to 10 LEDs in series. The boost converters run at 600kHz fixed switching frequency to reduce output ripple, improve conversion efficiency and allow for the use of small external components.



Typical application.

USB-Compliant Li-Ion Charger in 2mm x 2mm QFN

bq24040

Get samples and datasheets at: **www.ti.com/sc/device/bq24040**

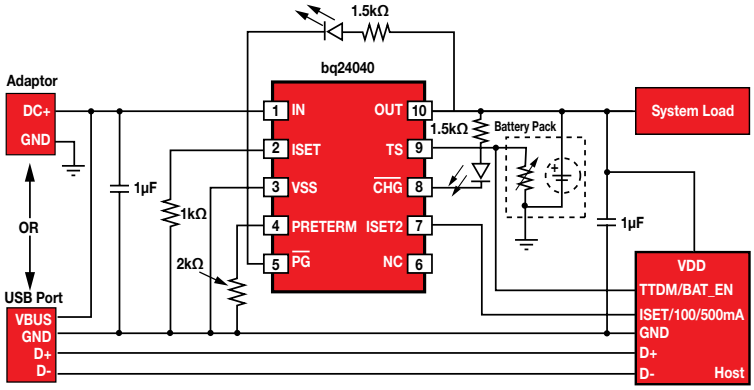
Key Features

- 30-V input rating and 6.6-V overvoltage protection
- Integrated 800-mA FET and current sensor
- USB compliance: USB current limiting and input voltage dynamic power management
- JEITA compliance: reduced charge current at cold and reduced charge voltage at hot
- Packaging: small 10-lead, 2mm x 2mm QFN

Applications

- Portable devices powered by 1-cell Li-Ion or Li-Pol batteries

The bq24040 operates from either a USB port or AC adapter. The 100mA /500mA current limit in USB mode fully complies with USB standard. The Input Dynamic Power Management feature reduces the charge current when the input voltage drops to an internal threshold, protecting the source from excessive loads. In addition, the bq24040 comes with more safety features: JEITA compliance, over-voltage protection, safety timers, and ISET short protection.



Functional block diagram.

Power Management

Pack-Side Impedance Track™ Fuel Gauge

bq27541

Get samples and application reports at: **www.ti.com/sc/device/bq27541**

Key Features

- Battery fuel gauge for 1-series Li-Ion applications
- Microcontroller peripheral provides:
  - Accurate battery fuel gauging
  - Internal temperature sensor for system temperature reporting
  - SHA-1/HMAC authentication
  - 96 bytes of nonvolatile scratch pad flash
- Battery fuel gauging based on patented Impedance Track™ technology
  - Models battery-discharge curve for accurate time-to-empty predictions
  - Automatically adjusts for battery aging, battery self-discharge and temperature/rate inefficiencies
  - Low-value sense resistor (10mΩ or less)
- SDQ, HDQ and I^2C interface formats for communication with host system
- Packaging: Small 12-pin, 2.5mm x 4mm SON

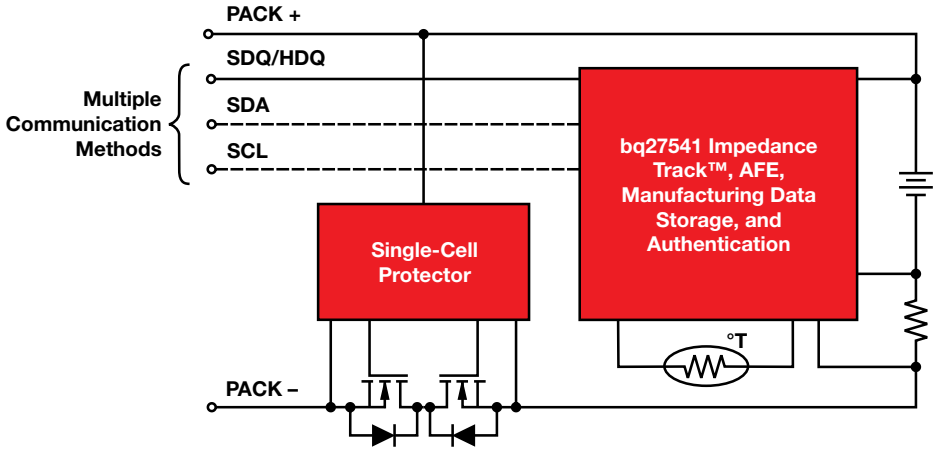
Applications

- Smartphones
- PDAs
- Digital still and video cameras
- Handheld terminals
- MP3 or multimedia players

TI's bq27541 Li-Ion battery fuel gauge is a microcontroller peripheral that provides fuel gauging for single-cell Li-Ion battery packs. The device requires little system microcontroller firmware development for accurate battery fuel gauging. The bq27541 resides within the battery pack or on the system's main board with an embedded (nonremovable) battery.

The bq27541 uses the patented Impedance Track™ algorithm for fuel gauging and provides information such as remaining battery capacity (mAh), state-of-charge (percent), run time to empty (min), battery voltage (mV) and temperature (°C).

The bq27541 also features integrated support for secure battery-pack authentication using the SHA-1/HMAC authentication algorithm.



Typical application.

Power Management

8-Channel Power-Supply Sequencer and Monitor

UCD9080

Get samples, datasheets, evaluation modules, application reports and software tools at: **www.ti.com/sc/device/ucd9080**

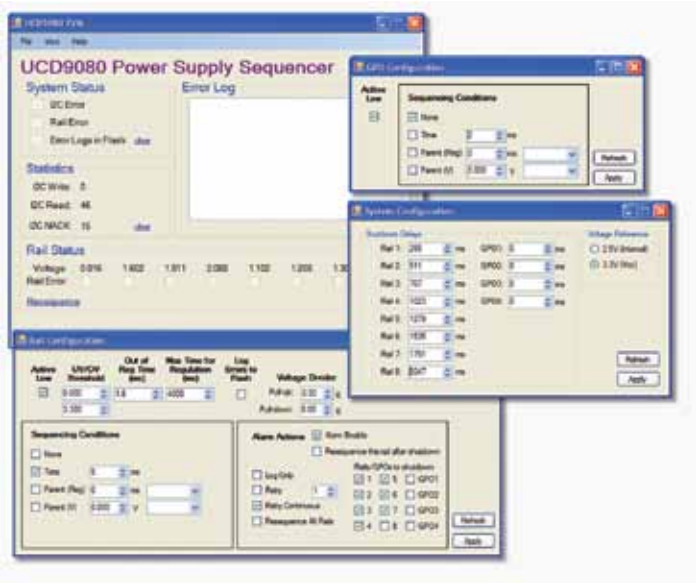
Key Features

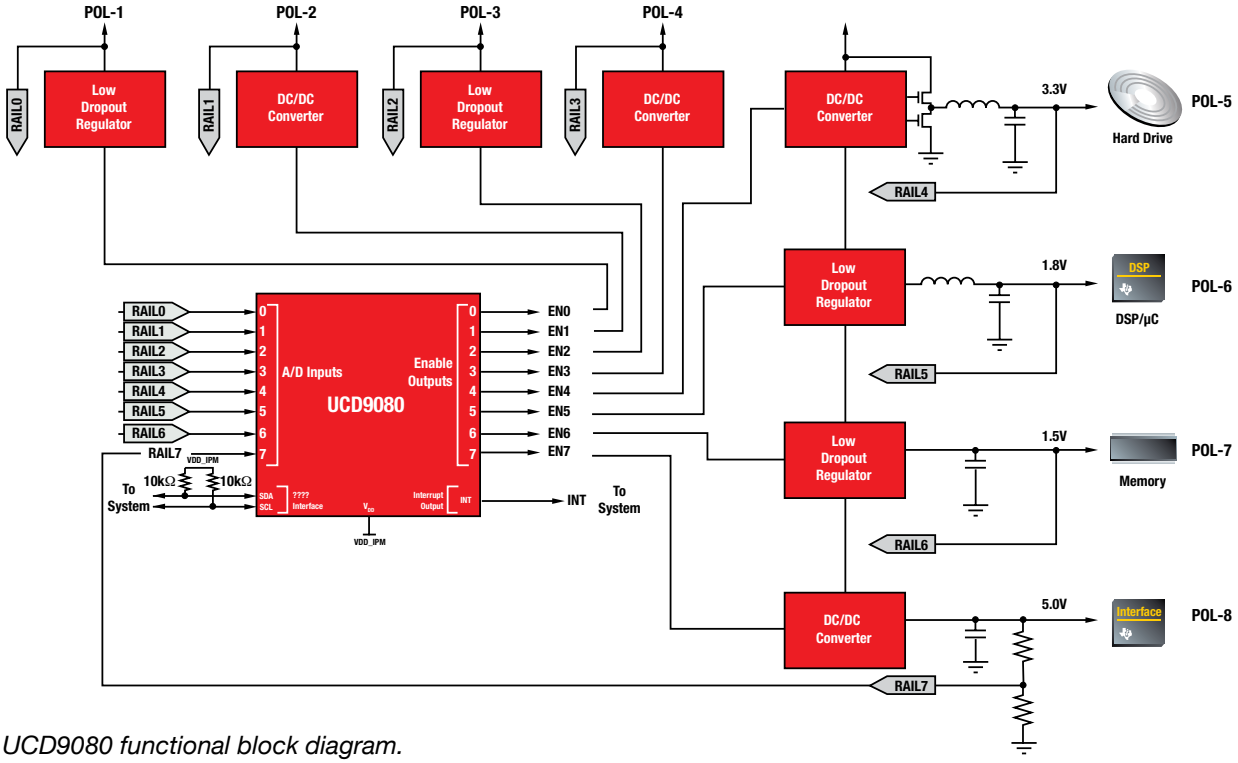
- Sequencing and monitoring of up to eight voltage rails
- All rails monitored and updated every 50µs 3.5mV resolution
- Sequencing of up to three digital outputs for power-on-reset and other functions
- Under- and overvoltage threshold per rail
- I^2C interface for configuration and monitoring
- Microsoft Windows GUI for configuration and monitoring
- Flexible rail shutdown
- Supply voltage: 3.3V
- Low power consumption: 300µA, 3.0V

Applications

- Telecommunications switch servers
- Networking equipment
- Test equipment
- Any system requiring sequencing of multiple voltage rails

Component	Description
UCD9111	Single-phase POL digital power controller
UCD9112	Dual-phase POL digital power controller
UCD9501	32-bit digital signal controller for power management
UCD7100	Digital control, single low-side ±4-A MOSFET driver with current sense
UCD7201	Digital control, dual low-side ±4-A MOSFET driver with single common current sense
UCD7230	Digital power-compatible synchronous buck driver





UCD9080 functional block diagram.

Power Management

Second-Generation PTH Point-of-Load Modules

PTH08T2xx

Get samples, datasheets, evaluation modules, application reports and software tools at: **www.ti.com/sc/device/pth08t210w**

Key Features

- TurboTrans™ technology
- 1.5% output regulation
- SmartSync synchronization
- Auto-Track™ sequencing

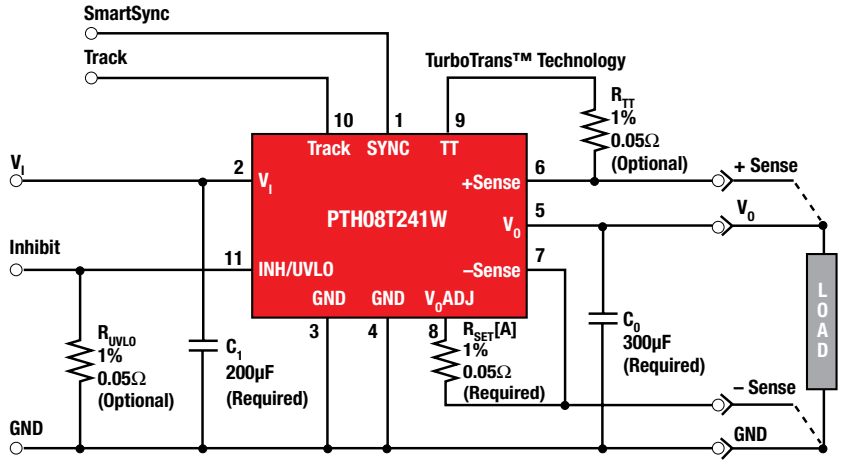
Benefits

T2s reduce development costs and save PCB space:

- Sequencing easily solved with Auto-Track technology
- SmartSync synchronization for input cap reduction/easier filtering
- TurboTrans technology for high transient load applications
- Stable with ultra-low ESR caps
- 1.5% tolerance meets specs of FPGA core

Typical Component Specifications

Model	V_{IN} (V)	V_{OUT} (V)	I_{OUT} (A)
PTH04T260W	2.2 to 5.5	0.7 to 3.6	3
PTH08T260/261W	4.5 to 14	0.7 to 5.5	3
PTH04T230W	2.2 to 5.5	0.7 to 3.6	6
PTH08T230/231W	4.5 to 14	0.7 to 5.5	6
PTH04T240/241W	2.2 to 5.5	0.7 to 3.6	10
PTH08T240/241W	4.5 to 14	0.7 to 5.5	10
PTH04T220W	2.2 to 5.5	0.7 to 3.6	16
PTH08T220/221W	4.5 to 14	0.7 to 5.5	16
PTH05T210W	2.2 to 5.5	0.7 to 3.6	30
PTH08T210W	4.5 to 14	0.7 to 3.6	30
PTH08T250W	4.5 to 14	0.7 to 3.6	50
PTV08T250W	8 to 14	0.8 to 3.6	50



PTH08T2xx functional block diagram.

100W, Isolated DC/DC Module

PTQA430033

Get samples, datasheets, evaluation modules, application reports and software tools at: **www.ti.com/sc/device/PTQA430033**

Key Features

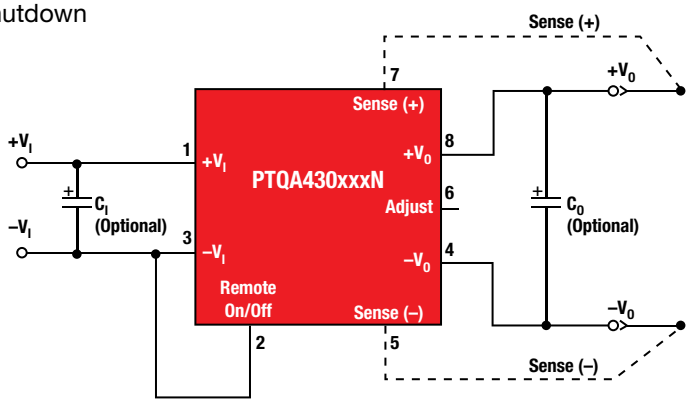
- 48V input (36V to 75V range)
- Standard quarter-brick footprint
- High efficiency (92 percent at 3.3V full load)
- 1500V DC I/O isolation
- On/off control
- Overcurrent protection
- Differential remote sense
- Undervoltage lockout
- Output overvoltage protection
- Overtemperature shutdown

Benefits

- Pin-compatible with industry-standard products
- Small size, high current applications

Typical Component Specifications

Model	Input (V)	Output Current (A)	Output (V)
PTQA	4	30	025
	4 = 48	30 = 30	025 = 2.5
		20 = 20	033 = 3.3
			050 = 5.0



PTQA430033 functional block diagram.

Power Management

Pack-Side Impedance Track™ Fuel Gauge

TPS27081A

Get samples, data sheets, evaluation modules and application reports at: **www.ti.com/sc/device/tps27081a**

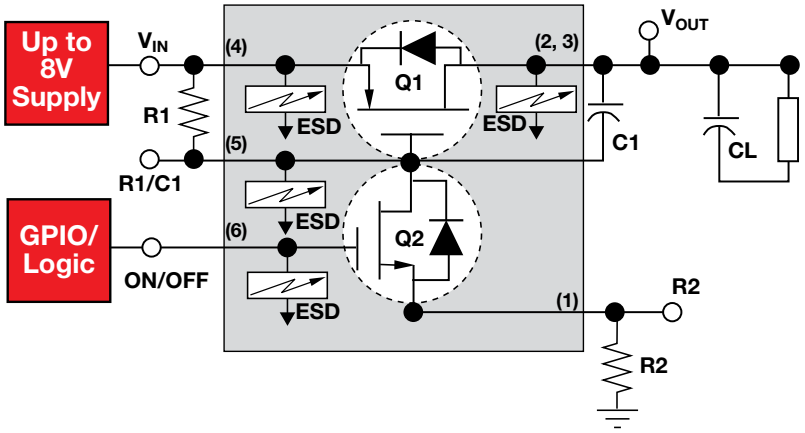
Key Features

- Low ON resistance, high current PFET
- Very high pulsed current rating
- Accurate Turn-ON and Turn-OFF slew rate
- Supports a wide range of 1.0V up to 8V Supply Inputs
- Compatible to 1.2V -5.5V GPIO interfaces
- Fully protected against ESD
- Ultra low leakage current in stand-by (typical ~100nA)

Applications

- High side load switch
- Inrush-current control
- Power sequencing and control
- Stand-by power isolation
- Portable power switch

The TPS27081A IC is a high side load switch that integrates a Power PFET and a Control NFET in a tiny package. The TPS27081A features industry-standard ESD protection on all pins providing better ESD compatibility with other on-board components. The TPS27081A level shifts ON/OFF logic signal to V_{IN} levels and supports as low as 1.0V CPU or MCU logic to control higher voltage power supplies without requiring an external level-shifter.



TPS27081A functional block diagram.

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
AC/DC and DC/DC Power Supply				
UCD7100	Digital Control Driver	Adjustable current limit, 3.3V, 10mA internal regulator	Applications requiring fast local peak current limit protection	
Battery Management				
bq24040	USB-Compliant Li-Ion Charger	30-V input rating and 6.6V overvoltage protection; integrated 800mA FET and current sensor; USB and JEITA compliant	The bq24040 comes with more safety features: JEITA compliance, over-voltage protection, safety timers, and ISET short protection	bq2409x
bq2406x	Battery Charger	Linear 1-cell Li-Ion charger with thermal regulation, 6.5V OVP, temp sense	Good for space-limited designs with need for battery safety	bq2410x
bq2407x	Battery Charger	Linear 1-cell Li-Ion 1.5A charger using either a USB or adapter voltage source. Features PowerPath management, dynamic power management, thermal regulation, OVP, and temperature Sensing.	Good for space-limited designs using USB and/ or adapter voltage sources with excellent charging capabilities	
bq24081	Battery Charger	One-cell Li-Ion charger with 1-A FET, timer enable and temperature sensing	Great for space-limited charger applications	
bq24100	Battery Charger	Switch mode, 1100kHz switching frequency, >2A charge current	d/dt, min current primary charge termination method	
bq24156A	Battery Charger	One-cell Li-Ion switch mode charger with 1.5A internal FET, I^2C interface for easy charging parameter setup with temperature sensing and status outputs	Switch mode operation efficiency, dynamic power mgmt, I^2C interface allows easy charger setup, internal FETs allow lower system cost and small size solutions	bq24153A
bq24703	Battery Charger	0V operation, ±0.4% charge voltage accuracy, integrated PWM	Dynamic power management, multichemistry	bq24702, bq24705
bq24721/C	Battery Charger	Multichemistry and multicell sync switch-mode charger	High efficiency, pack and system protection functions	bq24105
bq25504	Ultra-Low-Power Boost Battery Charger for Energy Harvesting	Specifically designed to efficiently acquire and manage microwatts (µW) to miliwatts (mW) of power generated from a variety of DC sources like photovoltaic (solar) or thermal electric generators	Implements a highly efficient boost converter/charger targeted toward products and systems, such as wireless sensor networks (WSN) which have stringent power and operational demands. The design of the bq25504 starts with a DC/DC boost converter/charger that requires only microwatts of power to begin operating.	
bq27410	Battery Fuel Gauge	Li-Ion battery gas gauge with Impedance Track™ fuel-gauge technology	Reports accurate time-to-empty of battery	bq27425
bq27541	Battery Fuel Gauge	Li-Ion battery gas gauge with Impedance Track™ fuel-gauge technology	Reports accurate time-to-empty of battery	bq27545
bq29330	Battery Safety	Battery pack full-protection analog front end	Provides individual cell voltages and battery voltage to battery management host	
bq2945xy	Overvoltage Protection Device for 2- to 3-Cell Li-Ion Batteries.	Secondary level voltage monitor and protector for Li-Ion battery pack systems	Each cell is monitored independently for an overvoltage condition	bq2946xy
bq30z55	Battery Fuel Gauge	2s to 4s Li-Ion battery gas gauge with Impedance Track™ fuel-gauge technology with built in protection	Provides accurate battery capacity along with providing protection and cvell balacing features	bq20z45, bq20z65, bq30z50
bq34z100	Battery Fuel Gauge	1s to 14s multichemistry battery fuel gauge	Support NiXX, Li-XXX and PbA battery dhemistries	
bq500210	Wireless Power Transmitter	Provides contactless Qi compliant 5W wireless power transmission	Wireless power important in many portable medical applications where a sealed enclosure is needed for sterile conditions, applications where operating in potentially explosive oxygen environments, applications with limited user dexterity, and others	
bq51013	Wireless Power Receiver	Provides contactless Qi compliant 5W wireless power supply	Wireless power important in many portable medical applications where a sealed enclosure is needed for sterile conditions, applications where operating in potentially explosive oxygen environments, applications with limited user dexterity, and others.	bq51013A
bq76925	3-6 Series Li-ion Battery Analog Front End (AFE)	The bq76925 allows a host controller to easily monitor individual cell voltages, pack current and temperature. Low ICC: 40uA normal mode, <2uA sleep. Internal cell balancing circuitry.	Provides AFE monitoring for safety for overvoltage, under voltage, over current, short circuit	bq77908A, bq77910A
bq77PL900	5-10 Series Li-ion Battery Protection and AFE	Integrated I^2C communications interface allows the bq77PL900 also to be as an analog front end (AFE) for a host controller	Provides full safety for overvoltage, under voltage, over current in discharge overvoltage and short circuit in discharge conditions	
bq78PL114	High Power and High Capacity Battery Pack Management Controller	Designed for managing 3- to 8-series cell battery systems, high-resolution 18-bit integrating delta-sigma Coulomb Counter for precise charge-flow measurements and gas gauging	Expandable from 3 to 12 Li-Ion cells in series, active cell balancing	bq76PL102

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Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
DC/DC Controllers				
TPS40040	DC/DC Buck Controller	2.25V to 5.5V step-down synchronous controller, low pin count	High efficiency, small size. FPGA Power	TPS40020
TPS40170	DC/DC Buck Controller	4.5V to 60V synchronous step-down controller with out of phase synchronization	Allows flexibility for the input and the switching frequency	TPS40060
TPS40210	DC/DC Controller	4.5V to 52V boost controller, low pin count	Supports Boost, Flyback, SEPIC topologies	TPS55340
TPS40304A	DC/DC Buck Controller	3V to 20V synchronous buck controller, Spread-spectrum frequency dithering	Low noise, FPGA Power	TPS40075
TPS40200	DC/DC Controller	4.5V to 52V input non-synchronous buck DC/DC controller	Very wide input allows wider range of solutions	
TPS43000	DC/DC Controller	1.8V to 8V synchronous controller, 2MHz boost, flyback, SEPIC. Battery applications	Allows smaller-value inductor and input cap	
TPS43060/1	4.5V to 38V Synchronous Boost Controller	Low quiescent current, high efficiency	Supports 5.5V or 7.5V gate drive, Ideal for USB charging applications for 2-3 series Li-Ion	
TPS51216	DC/DC Controller	Complete DDR/DDR2/DDR3 solution	Provides all output and active termination for DDR	
TPS53124	Dual DC/DC Controller	4.5V to 24V input, synchronous step-down, adaptive on-time (D-CAP)	Fast transient response, no loop compensation	TPS53127
DC/DC Converters				
DCH010505D	Galvanic Isolated, DC/DC Converters	1W, 3kV isolation, minimal external components	Safety isolation, removal of ground loops, reducing board space	DCH010512, DCH010515
DCP01B	DC/DC Converter	5V, 15V, 24V input bus, 1W, unregulated, dual, isolated	1W P_{OUT} or I_{OUT}, ±5V, ±12V, ±15V V_O range	DCP02
DCP020515D	Isolated DC/DC Converter	2W, unregulated, up to 89% efficiency, 106W/in3 power density	EN55022 Class B EMC performance, UL1950 component	DCP02 series
PTB48500A	DC/DC Converter	48V input bus, 30W, dual, isolated	30W P_{OUT} to I_{OUT}, 3.3V/1.2V V_O range	PTB48501A/B
TPS54040A	3.5V to 42V, 500mA Buck Converter	Frequency synchronization, MSOP10 or 3x3mm SON		TPS54060A
TPS54140A	3.5V to 42V, 1.5A Buck Converter	Frequency synchronization, MSOP10 or 3x3mm SON		TPS54160A
TPS54240	3.5V to 42V, 2.5A Buck Converter	Frequency synchronization, MSOP10 or 3x3mm SON		TPS54260
TPS54340	3.5V to 42V, 3.5A Buck Converter	Frequency synchronization, 8HSOIC		TPS54360
TPS54620	4.5V to 17V, 6A Step Down Converter	Synchronous, up to 1.6MHz, frequency synchronation, 3.5x3.5mm QFN package	High efficency, small size	TPS54320
TPS54678	2.95 to 6V, 6A Buck Converter	Synchronous, up to 2MHz, frequency synchronization, 3x3mm QFN package	High efficency, small size	TPS54478
TPS55010	2.95 to 6V, 2W Isolated DC/DC converter	Frequency synchronization, Primary side regulation, Fly-buck topology	Isolated 5V to 5V (and others) , no LDO needed, high efficiency	SN6501
TPS55340	Boost Converter	3V to 32V input, 5A Switch, up to 40V output, frequency synchronization, 1.2MHz, 3x3mm QFN	Small size, supports boost, flyback, and SEPIC topologies	TPS61175
TPS61070	DC/DC Converter	600mA switch low voltage in boost	Can generate 5V rail from 1-, 2- or 3-cell alkaline or 1-cell Li-Ion	
TPS61093	OLED Boost Converter	Wide V_{IN} range, input-output disconnect	Flexible, fail safe solution	TPS61080
TPS61097-33	Boost Converter with Bypass Switch	Highly efficient, operates down to 0.3V; bypass switch; 5nA shutdown current; SOT-23	Super efficient boost, works over entire battery range, low quiescent current, integrate the bypass switch, small package	
TPS61120	DC/DC Converter	Dual switcher boost and LDO	Compact 2-voltage solution	
TPS61160/61	Boost Converter	2.7V to 18V input voltage, up to 90% efficiency, built-in soft start	The boost converter runs at 600kHz fixed switching frequency to reduce output ripple, improve conversion efficiency, and allows for the use of small external components	
TPS61200	Boost Converter	High efficient, operates down to 0.3V	Super efficient boost, works over entire battery range	TPS61010
TPS61220	Boost Converter	Down to 0.7V V_{IN} operation, pass-through function	Simple, small, low power solution	TPS61070
TPS61240	Boost Converter	Input current limit, load disconnect during shutdown	Small, fail save solution	TPS61070
TPS62040	DC/DC Converter	Adjustable 1.2A, 95%-efficient step-down converter, 18µA, MSOP-10	Maximizes battery life with high efficiency and low IQ	
TPS6206x	Step-Down Regulator	High frequency operation, 2x2 QFN package,power save mode	High efficiency, small solution size	TPS62290
TPS62110	Step-Down Regulator	3.1V to 17V V_{IN}, 1.5A conversion, synchronization pin, Low battery indicator, power save mode	Very low noise/high efficiency	TPS62050

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New products are listed in ***bold red****.*

Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
DC/DC Converters (continued)				
TPS62202	DC/DC Converters	300mA synchronous	Ultra-small battery-powered solutions	
TPS62220	DC/DC Converter	300mA step-down converter in a SOT-23 package	Small solution size with high-side FET	
TPS62230	Step-Down Regulator	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62300/1/2/3/5	Step-Down Regulator	500mA, 3MHz synchronous step-down converter	Very small inductor and high efficiency	TPS62040
TPS62350	DC/DC Converter	Step-down DC/DC converter with I^{2}C interface for dynamic voltage scaling	Provides ability to increase conversion efficiency	
TPS62400	Step-Down Regulator	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410
TPS62420	Step-Down Regulator	Dual step-down buck converter with 1-pin easy scale	Offers dynamic voltage scaling for power savings	
TPS62750	Step-Down Regulator	Programmable input current limit, hot plug and reverse current protection	Supports USB powered applications and large output caps	TPS62040
TPS63000	Buck Boost Converter	Automatic transition between step down and boost mode	Produce mid-range voltage out over entire range of battery	TPS621130
TPS63030	Buck-Boost Converter	1-A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
Hot Swap and Power Distribution				
TPS22902	Load Switch with Controller Turn-On	Low on resistance, controlled turn-on, ultra small 0.64mm^2 package, quick output discharge	Ultra-small, fully integrated solution	TPS22901, TPS22922, TPS22924C, TPS22960
TPS22946	Current Limited Load Switch	Configurable current limit, ultra-small package, 1µA quiescent current at 1.8V	Ultra-small, low quiescent current current limited switch	TPS22949, TPS22945
TPS23750	Power-over-Ethernet	PoE interface and DC/DC controller in one IC	Transmit power and data to remote devices over Ethernet cable	TPS23753
TPS23753	Power-over-Ethernet	PoE with AC adaptor ORing function	Allows 12V adaptor ORing	
TPS2551	Power Switch	Adjustable current limit, 100mA to 1100mA	Allows designer to precisely set current limit	TPS2051B, TPS2061
TPS27081A	P+N High Side Load Switch	Low ON resistance, high current PFET. Very high pulsed current rating. Accurate Turn-ON and Turn-OFF slew rate. Supports a wide range of 1.0V up to 8V Supply Inputs.	Wide supply range. Low quiescent current replacement for discrete FETs.	TPS27082L
Lighting and Display Solutions				
TPS65120	DC/DC Converter	5V/20mA (I/O), 4-ch high-accuracy multi-converter w/3.3V LDO for LCD bias	Complete solution in one package	
TPS65123	DC/DC Converter	5V/20mA (I/O), 4-ch high-accuracy multi-converter w/o LDO for LCD bias	Complete solution in one package	
TPS65124	DC/DC Converter	5V/20mA (I/O), 4-ch high-accuracy multi-converter w/o LDO and w/programmable seq. for LCD bias	Complete solution in one package	
TPS65130	Boost Converter	800mA switch, adjustable, dual output, positive/ negative boost	Two supplies from one switcher	
Linear Regulators				
LP2950x	100-mA Low-Dropout Adjustable and Fixed-Voltage Regulators	Wide input voltage range up to 30V. Rated output current of 100mA. Low dropout: 380 mV typ. Low quiescent current 75µA (typ)	Easy-to-use with wide input voltage range and low dropout	LP2951x
LP2981x	100-mA Ultra-Low-Dropout Fixed Regulators with Shutdown	Output tolerance of 0.75% or 1.25%. Ultra-low dropout, 200mV (typ). Low quiescent current. Shutdown current: 0.01µA (typ)	Ultra-low dropout, low quiescent current, shutdown and small packaging	
LP2985x	150 mA Low-Noise Low-Dropout Fixed Regulators with Shutdown	Output tolerance of 1% or 1.5%. Ultra-low dropout 280 mV (Typ). Shutdown current 0.01mA (Typ). Low noise 30µV_{RMS}	Low dropout, low quiescent current, shutdown, low-ESR capacitor-friendly, low noise and small packaging	
TL750x	750-mA and 150-mA Low-Dropout Fixed-Voltage Regulators	Very low dropout voltage, less than 0.6V at 150mA or 750mA. Very low quiescent current. 60-V load-dump protection	Very low drop out voltage with extremely low quiescent current.	TL751x
TLV1117	800-mA Low-Dropout Adjustable and Fixed-Voltage Regulators	1.5-V, 1.8-V, 2.5-V, 3.3-V, 5-V and adjustable-output voltage options. Output current of 800mA.	Very efficient and stable	LM317, TL431, TLV431, TLVH431, TLVH432, UA7805
TPS2051C	USB Power Switch	USB compliant power source, short circuit protection	USB switch accurate Ilimit and fast turn off	TPS2065C
TPS2511	USB Switch with BC1.2 Charging Control	USB compliant and able to handshake with BC1.2 compliant clients	USB switch allows charging of peripheral devices with no uC support	TPS2540/40A/41/ 41A/43

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New products are listed in ***bold red****.*

Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Linear Regulators (Continued)				
TPS2552/3	Precision Adjustable USB Power Switch	Family of precision adjustable current limit devices	Accurate limits provide greater protection and require less supply margining	TPS2554/5/6/7
TPS3839	Supervisor and Reset IC	Ultra-low 150nA, ultra-small voltage supervisor	monitors voltage rails and provides high accuracy reset	TPS3808
TPS7A3001	Low-Noise Negative Voltage (–36V) LDO	V_{IN} -3V to -36V, -200mA, ultra-low noise, High PSRR, low-dropout linear regulator	Low-noise negative power rails for sensitive analog components	
TPS7A4700	Lowest-Noise 1A High Voltage (36V) LDO	Low noise (3µVrms), 1A, high voltage low-dropout linear regulator	Low-noise power rails for sensitive analog components	TPS7a3301
TPS7A4901	Low-Noise High Voltage (36V) LDO	V_{IN} 3V to 36V, 150mA, ultra-low noise, high PSRR, low-dropout linear regulator	Low-noise power rails for sensitive analog components	
TPS717xx	Low-Noise Single-Channel LDO	High bandwidth, very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS799xx
TPS75005	PMU	Dual, 500mA low-dropout regulators and triple voltage rail monitor	Core and I/O voltage rails in one LDO	
TPS71710	Low-Noise Single-Channel LDO	High bandwidth, very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS759xx, TPS739xx
TPS717xx	Low-Noise Single-Channel LDO	High bandwidth, very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS799xx
TPS718	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719
TPS72501	LDO	Single-output LDO, 1.0A, adjustable (1.22V to 5.5V), any cap, low-input voltage, integrated SVS	Combines the LDO and SVS function in one small package to save space	TPS726xx family
TPS727xx	Single Channel LDO	High PSRR/low noise/ultra low IQ	Battery power applications	TPS717xx
TPS73025	LDO	Single-output LDO, 200mA, fixed (2.5V), high PSRR, low noise	High PSRR requires less noise filtering in sensitive applications	
TPS73028	LDO	Single-output LDO, 200mA, fixed (2.8V), high PSRR, low noise	High PSRR requires less noise filtering in sensitive applications	
TPS73101	LDO	Single-output LDO, 150mA, adjustable (1.2V to 5.5V), cap free, low noise, fast transient response	Responds to transients faster to keep output voltage in regulation	TPS725xx family
TPS74201	LDO	Single-output LDO, 1.5A, adjustable (0.8V to 3.3V), any or no cap, programmable soft start	Adjust the voltage ramp rate for your processor requirements	
TPS74301	LDO	Single-output LDO, 1.5A, adjustable (0.8V to 3.3V), any or no cap, programmable soft start	Adjust the voltage ramp rate for your processor requirements	
TPS74401	LDO	Single-output LDO, 3.0A, adjustable (0.8V to 3.3V), fast transient response, programmable soft start	Adjust the voltage ramp rate for your processor requirements	
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat	
TPS75105	LDO	Low-dropout, two-bank LED driver with PWM brightness control	Will allow stepped brightness adjustment	
TPS76725	LDO	1A single-output LDO with low IQ and fast transient response	Efficient design allows quick response to dynamic current requirements	
TPS76733	LDO	1A LDO with fastest transient response plus ultra-low supply current	Ultra-low 85µA supply current and 230mV dropout voltage stretch battery life	
TPS76750	LDO	1A LDO with fastest transient response plus ultra-low supply current	Ultra-low 85µA supply current and 230mV dropout voltage stretch battery life	
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low IQ 500nA	DVS voltage designed to operate with MSP430™ to increase power savings	TPS781xx
TPS79718	LDO	Single-output LDO, 50mA, fixed (1.8V), low quiescent current, power-good output	Better battery life with PG signal for the processor	
TPS79730	LDO	Single-output LDO, 50mA, fixed (3.0V), low quiescent current, power-good output	Better battery life with PG signal for the processor	
TPS79901	Single Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS79501, TPS74301
TPS79912	LDO	High-performance 200mA in chip-scale package	Very small solution size	
TPS79925	LDO	High-performance 200mA in chip-scale package	Very small solution size	
MOSFET Drivers				
TPS2811	MOSFET Driver	Inverting dual high-speed MOSFET drivers with internal regulator	Saves solution space	
TPS2828	MOSFET Driver	2A output, 14ns rise and fall time, 24ns prop delay, inverting	Drives FETs for high-voltage transformer	TPS2829 non-inverting version
UCC37321	Single 9A Peak Low-Side MOSFET driver	High-speed, 20ns typical rise and fall times	Industry standard pin-out, handles extreme Miller currents	UCC37323

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*New products are listed in **bold red**. Preview products are listed in **bold blue**.*

Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Motor Drivers				
DRV8301	3-Phase Brushless Pre-Driver	On-chip 1.5A step-down converter and dual low side current sense amps; wide supply range (8V to 60V)	Reduced board space and component count; perfect fit for medical pump applications	DRV8302
DRV8312	3-Phase Brushless Driver	3.5A RMS / 6.5A Peak output current; independent 1/2 bridge control	High output current without any heat sink; can also drive solenoids / relays	DRV8313
DRV8818	2.5A Stepper Driver	On-chip 1/8 micro-step indexer; low RDSON FETs	Smooth motion profile without MCU support; excellent thermal performance; target applications include blood / urine analyzers	DRV8811, DRV8824, DRV8825
DRV8833	2A Low Voltage Stepper/Brushed DC Driver	2.7 to 10.8V supply range; on-chip current regulation; low RDSON FETs	Extended battery life; supports brushed or stepper motors; target applications include insulin pumps	DRV8834
DRV8839	1.8A Low Voltage Brushed DC Driver	1.8 to 11V supply range; low RDSON FETs; independent 1/2 bridge control	Extended battery life; can drive solenoids and relays; target applications include blood pressure monitors	DRV8837
DRV8844	Quad 1.75A Solenoid / Relay Driver	8 to 60V supply range; on-chip 10mA LDO; independent 1/2 bridge control	Flexible output configurations support 1x, 2x or 4X brushed DC motors or relay/solenoids	DRV8806
PMI Solutions				
TPS65010	Linear Charge Management	Multi-channel 1-cell Li-Ion power management IC, USB/AC charger, 2 DC/DCs, 2 LDOs, I^2C interface	Provides complete solution in one package	
TPS65020	Linear Charge Management	6-channel power management IC with 3 DC/DCs, 3 LDOs, I^2C interface and dynamic voltage scaling	Provides complete solution in one package	
TPS65023	Linear Charge Management	6-channel power management IC with 3 DC/DCs, 3 LDOs, I^2C interface and DVS, optimized for DaVinci™ DSPs	Provides complete DaVinci solution in one package	
TPS65073	PMU with charger and WLED	Integrates charger, WLED, DC/DC and LDO	Highest integration for portable applications	TPS650250
TPS65800	Linear Charge Management	6-channel power management IC with 2 DC/DCs, 7 LDOs, I^2C interface and dynamic voltage scaling	Complete power management solution in one package	
TPS75003	Linear Charge Management	Integrated triple-supply power management IC for Xilinx® Spartan®	Provides all three rails in one package	
Power Modules				
PTH04T240	Power Module	10A, 2.2V to 5.5V V_{IN}, adjustable V_{OUT}, with TurboTrans™ Technology	Complete power supply designed to meet ultra-fast transient requirements	PTH04T241
PTH08T220	Power Module	16A, 4.5V to 14V V_{IN}, adjustable V_{OUT}, with TurboTrans Technology	Complete power supply designed to meet ultra-fast transient requirements	PTH08T221
PTQA430033	Isolated DC/DC Module	100W, 1500V DC isolation, differential remote sense	High efficiency, industry-standard pin-compatible	PTQB425080
PWM Controller				
UCC38C4x	PWM Controller	14.9/9V on/off UVLO thresholds, 1MHz frequency, 50% duty cycle		UCC3804, UCC3809
Sequencer				
UCD90120	12-Channel Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124
Supervisor and Reset ICs				
TPS3103E12	Supervisory Circuit	Ultra-low-supply-current/supply-voltage supervisory circuit	Saves battery power	
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS3808Gxx	Voltage Supervisor	Low quiescent current, programmable-delay	Circuit initialization and timing supervision	TPS310x
TPS3813I50	Supervisory Circuit	Supervisor with programmable watchdog window	Allows custom time intervals	
TPS3836	Voltage Supervisor	220nA supervisor with 10ms/200ms selectable delay time	Circuit initialization and timing supervision	TPS3809
TPS386000	4-Channel Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808

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Component Recommendations

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
White LED Drivers				
TPS61040	White LED Driver	28V boost converter for white-LED supply	Allows ultra-small two- or three-cell alkaline or one-cell Li-Ion operation	
TPS61042	LED Boost Converter	Current source with overvoltage protection	Simple backlight boost for improved visibility of LCD	TPS61140
TPS61050	White LED Driver	1.2A high-power white LED driver with I^2C-compatible interface	Provides I^2C control	TPS61058
TPS61081	LED Boost Converter	Input-to-output isolation	Protection from short between any pins and between any pin to ground	TPS61042
TPS61140	White LED Driver	Dual, 2x 27V, 700mA switch, 1.2MHz boost converter with single-inductor white LED and OLED driver	High switching frequency requires smaller inductor and input capacitor	
LED Drivers				
DRV777	Integrated Motor and Load Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, low output VOL 0.4V Very low input leakage (<20uA)	Easy to use and low noise with Inductive kickback protection	
ULN2003LV	Low Power 3.3V and 5V Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, switching at 8V, low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	ULN2003A, ULN2003V12, ULN2004A, ULN2803A
ULN2003V12	Low Power Relay Driver	7-Channel, 1.8V, 3.3V, 5V CMOS, Switching at 16V low output VOL of 0.4V, delay time 80ns (typ)	Easy to use and low power dissipation	

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Enhanced Products

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- Extended temperature performance (typically -55°C to +125°C)
- Standalone data sheet
- Qualification pedigree
- Product traceability
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- Package performance is confirmed over extended temperatures (some mold compounds are not suitable for extended temperatures).
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- Customer defined qualification
  - QML Class Q (MIL-STD)
  - QML Class V (Space)
  - Additional options available

Typical processing and capabilities include:

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For more information regarding TI's Die and Wafer offerings, visit **www.ti.com/hirel** or email: **diesales@list.ti.com**

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