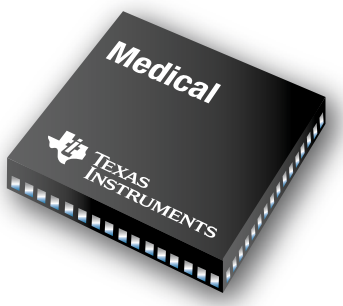
Medical Applications Guide



Texas Instruments

Continua Health Alliance

Consumer Medical

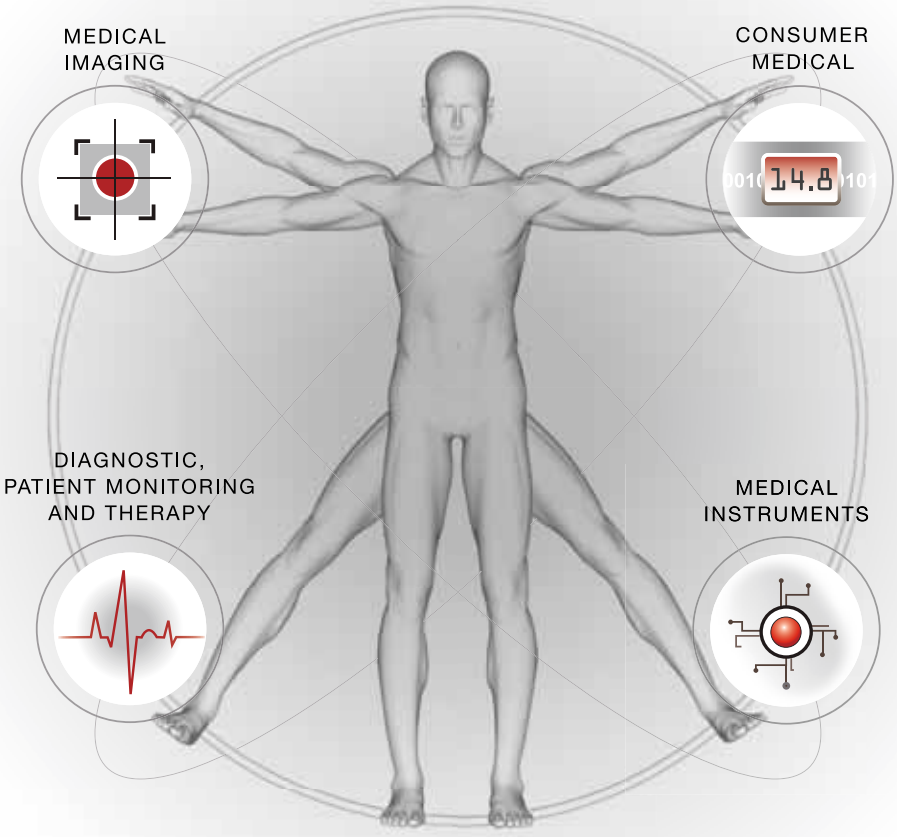
Diagnostic, Patient Monitoring and Therapy

Medical Imaging

Medical Instruments

Connectivity Solutions

Resources



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TI's Medical Applications Guides available for individual download:

- **Consumer Medical**
- **Diagnostic, Patient Monitoring and Therapy**
- **Medical Imaging**
- **Medical Instruments**

Visit:
www.ti.com/medicalguides

Introduction

With its full range of analog and embedded processing products, from building blocks to complete semiconductor solutions, plus systems insight, global support infrastructure, advanced process technology and medical industry involvement, TI is helping make innovative medical electronics more flexible, affordable and accessible.

TI's experience in diverse markets such as wireless communications, consumer electronics, automotive and aerospace enables engineers to meet increasing needs for higher speeds, higher precision, lower power and smaller equipment while maintaining the high standards for quality and reliability that the medical market demands.

Why TI?

Innovative Semiconductor Solutions

- Making advanced medical devices more flexible, affordable and accessible
- Addressing growing needs for portability, wireless connectivity, energy efficiency, performance and precision
- State-of-the-art process technology

Complete Portfolio

- Amplifiers, data converters, interfaces, power management, logic, DSPs, ultra-low-power MCUs, ARM-based MPUs, wired and wireless connectivity, audio and video ICs
- Catalog, application-specific, enhanced and custom ICs, plus die sales options

Quality and Reliability

- Long product lifetimes and a robust product obsolescence policy to ensure continuity of supply
- Ability to serve customers of all sizes with a variety of needs
- Enhanced qualification and screening available with enhanced package offering
- Member of industry-standard organizations and alliances, such as the Continua Health Alliance
- Robust process change control notification (PCN) and industry leading product traceability

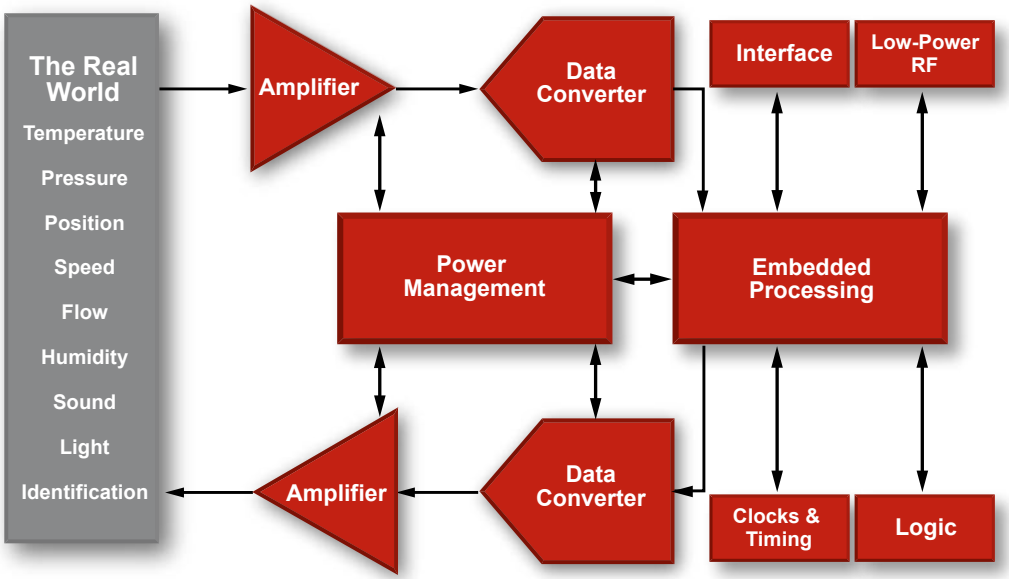
Commitment

- Experience in supplying components for a wide range of medical applications
- Global support infrastructure
- Local technical support and distribution
- Systems and applications insight
- Tools and training

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

You will find solutions and support for your medical applications design in the following segments, which are also available at www.ti.com/medicalguides for individual chapter download:

- Consumer medical
- Diagnostic, patient monitoring and therapy
- Medical imaging
- Medical instruments



Analog connects the digital and real worlds.

Overview

Five common system blocks are used when designing everything from blood glucose, digital blood pressure and blood cholesterol meters to health and fitness monitors such as digital pulse/heart rate monitors and digital thermometers. These blocks are:

- Power/battery management
- Control and data processing
- Sensor interface, amplification and analog-to-digital conversion
- User interface and display
- Wireless connectivity
  (see chapter on connectivity solutions)

While all battery-operated, microcontroller-based handheld devices take measurements using various bio-sensors, the block implementation topology differs greatly with the sensing, processing and information demands of the meter type and feature set.

For more information on TI's offering for Consumer Medical, please visit *www.ti.com/consumermedical*

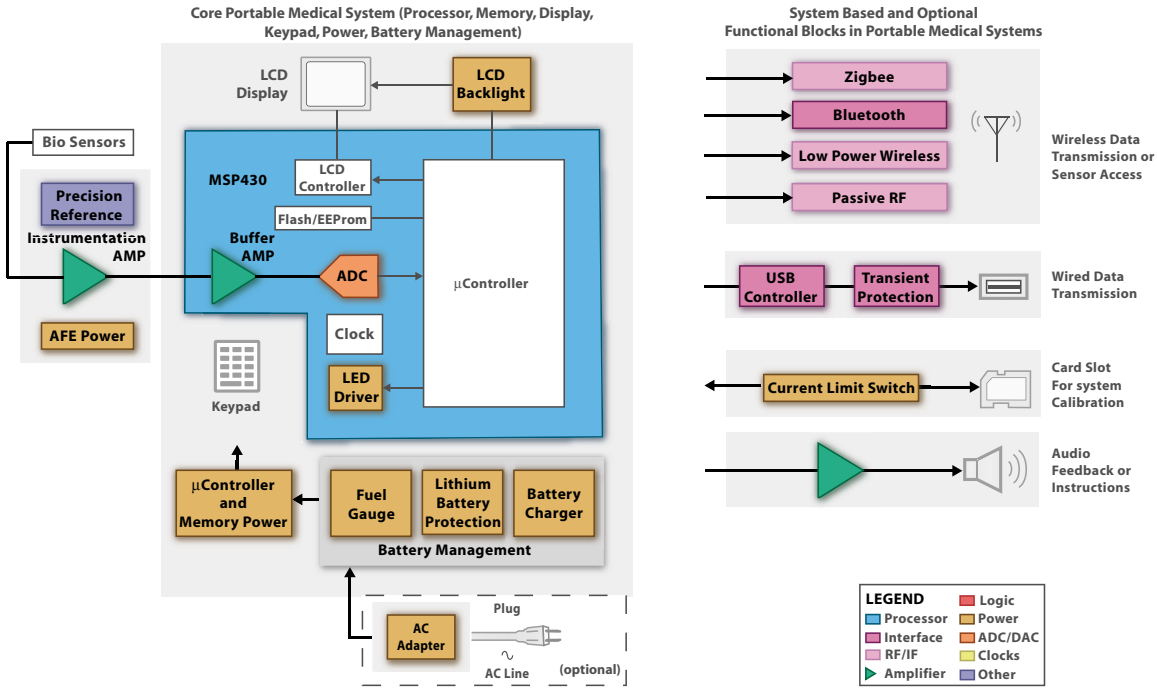
The design goals for extended battery life, high precision and fast response times are driven by the user's desire to quickly know their health status. Additional requirements may drive the need for more memory to allow for historical profiling, cabled or wireless interfaces for data upload or for access 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 can help you create the solutions. We offer a broad portfolio of processors, ranging from the high performance OMAP™ platform-based application processors, to digital signal processors (DSPs), ARM-based Sitara™ MPUs and ultra-low-power MSP430™ microcontrollers (MCUs) as well as the full range of high performance analog solutions with instrumentation, operational and buffer amplifiers, data converters, power and battery management components, audio amplifiers, and both wired and wireless interface components.

Connectivity for portable medical applications has become critical as consumers and caregivers are requiring data to move from medical devices to data hubs such as computers and mobile phones. TI is a promoting member of the Continua Health Alliance and now offers the first Continua-certified USB platform for Agent Devices. *See page 142 for more information.*

Continua HEALTH ALLIANCE

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



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 medical meters system block diagram.

Blood Pressure and Heart Rate/Fitness Monitoring Systems

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.

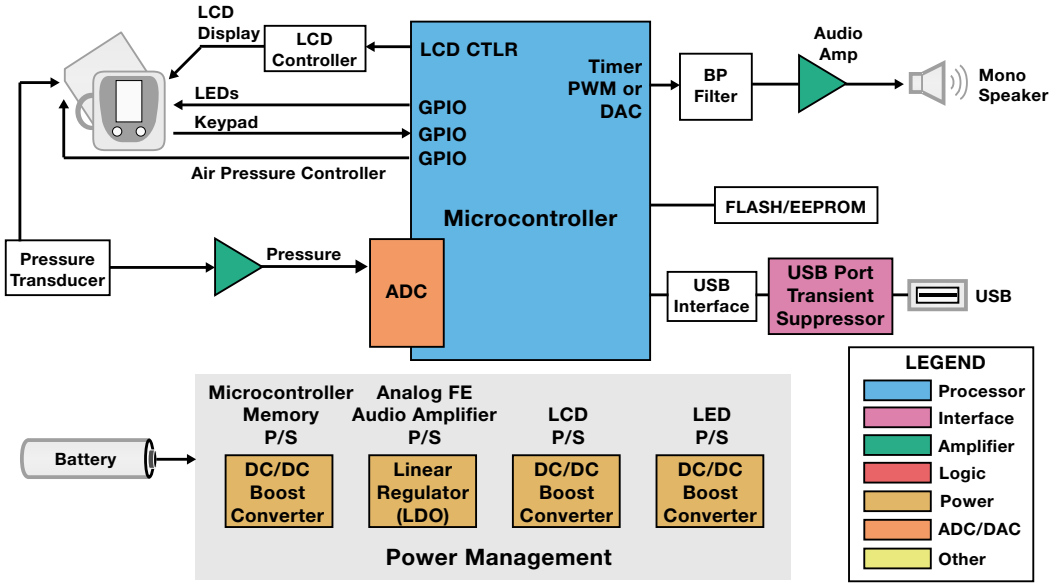
The core subsystems include:

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.



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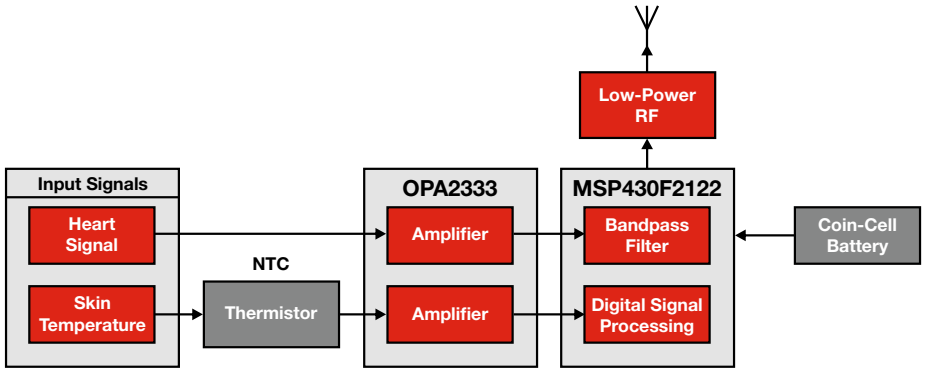
Example application block diagram — blood pressure monitor.

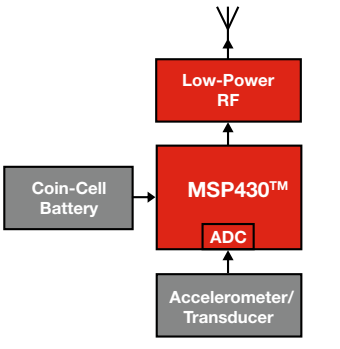
Heart Rate/Fitness Monitors

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.

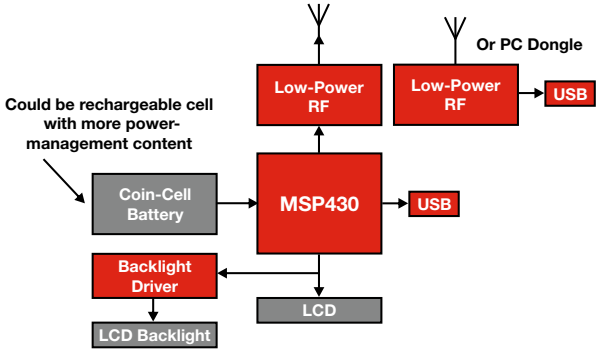
Note: "Heart Rate and EKG Monitor using the MSP430FG439" (slaa280)
www-s.ti.com/sc/techlit/slaa280



Heart rate monitor.



Shoe/footstrike sensor.



Wrist display/watch.

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.

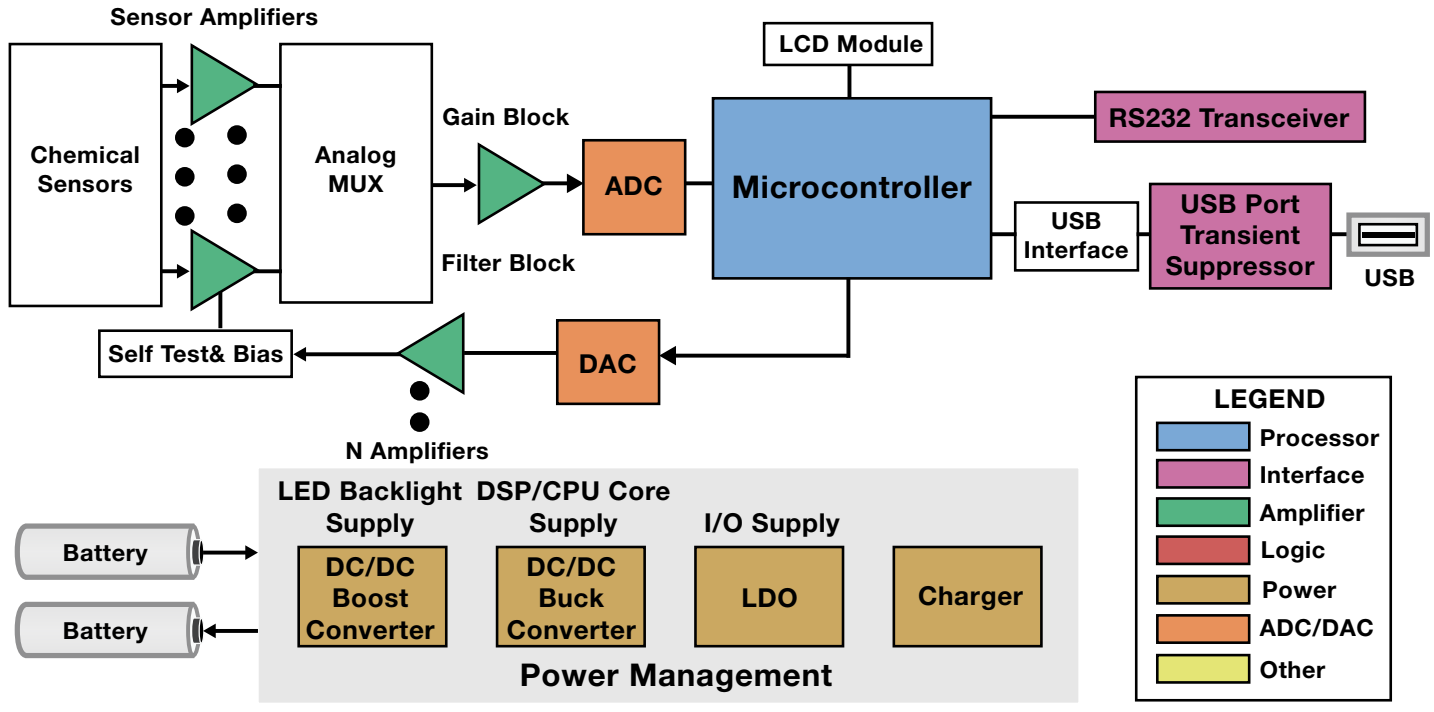
The measurement sequence is usually controlled by a microcontroller (MCU). The MCU also processes the conversion results, storing the measurements in an EEPROM or Flash memory and controlling other functions such as the keypad, real-time clock, sound/speech compression and serial communication to a connected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

See example block diagram on pg. 4.

MEDICAL DESIGN EXCELLENCE AWARDS® SUPPLIER TO A 2009 WINNER

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



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 blood gas analyzer block diagram.

Digital Thermometers

Digital Thermometers

Digital thermometers are quickly replacing traditional mercury thermometers because they are fast, accurate and effective, without the environmental risk. With newer technologies, different types of digital thermometers are classified based on the location where they are used, such as oral, rectal, underarm, ear, etc. The ear thermometer measures infrared eardrum heat, which reflects hypothalamus temperature — the temperature-controlling system of the brain. Infrared sensors are used in ear thermometers for measurement, while thermopiles or thermistors may be used in other thermometer types.

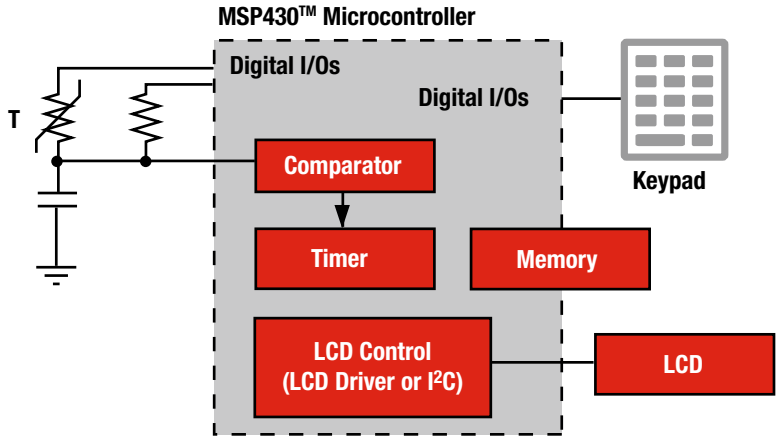
High-end thermometers have a number of thermopiles or thermistors whose resistance changes with temperature. The resistance change is measured as a change in voltage. This analog voltage is converted digitally by an analog-to-digital converter (ADC). The ADC's speed and resolution depends on the accuracy and time at which information is needed.

If an ADC module is not available, it is possible to digitize the analog signal using a comparator and a timer for slope analog-to-digital conversion. This method is generally used in low-cost digital thermometers. The single slope conversion measures temperature. Capacitance, supply voltage and frequency changes caused by aging or temperature drift can be compensated using a ratiometric measurement principle.

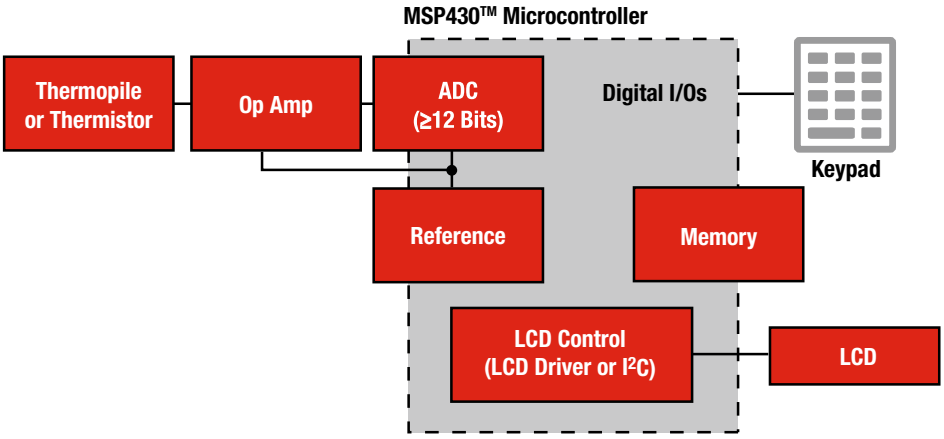
Note: "Implementing an Ultra-Low-Power Thermostat with Slope A/D Conversion" (slaa129B)
www-s.ti.com/sc/techlit/slaa129b

The block diagrams represent low-end general-purpose and high-end digital thermometers. Typical ADC resolution used in general-purpose digital thermometers may be 12-bit and above depending on the required accuracy level. Good ADC reference is required for better accuracy. A microcontroller may be used for control purposes. Low-cost solutions employ a low-cost, low-power microcontroller like the MSP430, which has the integrated comparator and timer needed to digitize the analog signal using the slope analog-to-digital conversion technique.

Features like high-temperature alarm, beep after measurement, auto shut-off and a data log of previous temperatures are optional. Most thermometers have easy-to-read displays, usually a LCD display and low-battery indicator. Other peripherals include digital I/Os and LCD drivers.



A general block diagram of a low-cost digital thermometer.



A general block diagram of a digital thermometer with high accuracy.

Consumer Medical General

Ultra-Low-Power PaLFI (Passive Low Frequency Interface)

TMS37157

Get samples and datasheets at: **www.ti.com/sc/device/TMS37157**

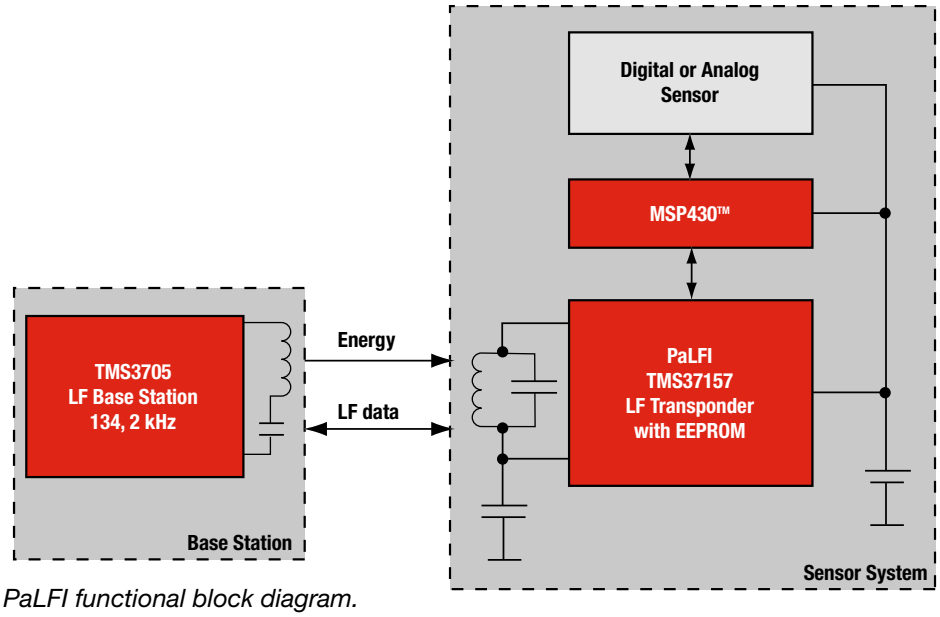
Key Features

- Wide supply voltage range 2V to 3.6V
- Ultra-low power consumption
  - Active mode max. 150µA
  - Power down mode 60nA
- Battery check and battery charge function
- Resonance frequency: 134.2kHz
- Integrated resonance frequency trimming

Applications

- Portable medical devices
- Implantable devices
- Measurement instruments
- Energy harvesting

The PaLFI combines a low-frequency transponder with an SPI interface and power management to a connected MSP430™ microcontroller. It is the ideal device for any data logger, sensor or remote control application enabling operation without the need of a battery.



PaLFI functional block diagram.

TMS37157

PaLFI – Passive Low Frequency Interface	
Communication Interfaces	SPI, RFID, direct microcontroller access via RFID
Operating Frequency	134.2kHz
Wired Communication Interface	3-wire SPI
Operating Voltage	2V to 3.6Vdc
Current Consumption	Active mode max: 150µA Power down mode: 60nA
Battery Charge Current	Max: 2mA
Memory	32-bit unique serial number 968-bit EEPROM user memory 8-bit selective address
Operating Temperature	–40°C to 85°C
Storage Temperature	–40°C to 125°C
Package	16-Pin VQFN (4mm × 4mm)
Packing/Delivery	Tape-on reel, 3000 per reel

Consumer Medical General

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

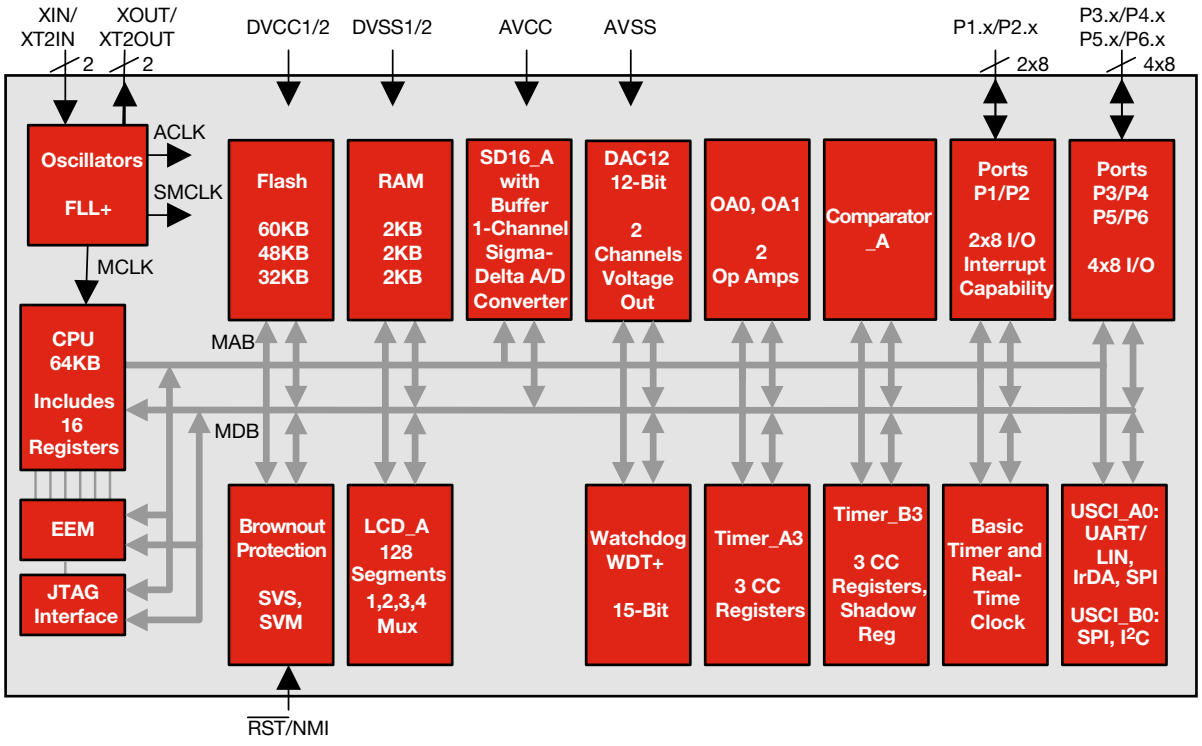
Applications

- 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.

Consumer Medical General

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**, **MSP430F5419A**, **MSP430F5435A**, **MSP430F5436A**, **MSP430F5437A** or **MSP430F5438A**)

Key Features

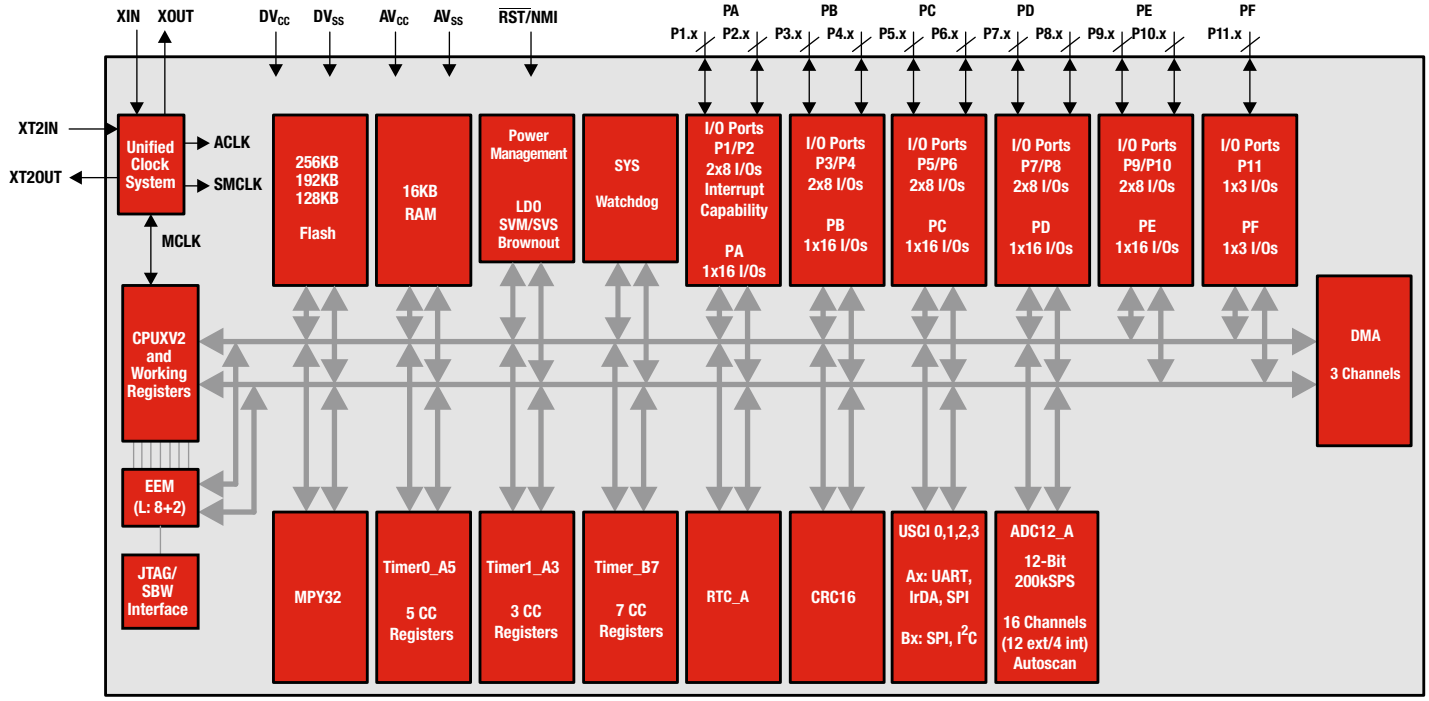
- Low supply-voltage range: 1.8V to 3.6V
- Ultra-low power consumption:
  - Active mode: 230µA/MHz
  - Standby mode (LPM3 RTC mode): 2.6µA
  - Off mode (LPM4 RAM retention): 1.6µA
  - Shutdown mode (LPM5): 0.1µA
- Wakes up from standby mode in less than 5µs
- 16-bit RISC architecture:
  - Extended memory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

Applications

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

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.

Consumer Medical General

Low-Power Precision Instrumentation Amplifier

INA333

Get samples and datasheets at: **www.ti.com/sc/device/INA333**

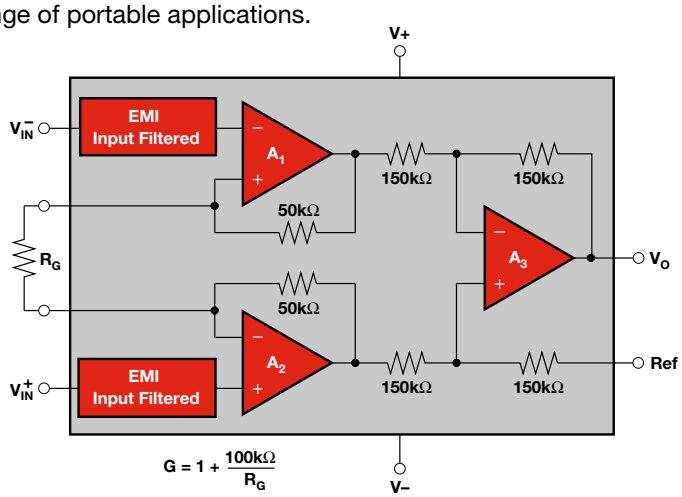
Key Features

- Low offset voltage: 20µV (max)
- Low drift: 50nV/°C
- Low input bias current: 200pA (max)
- Low noise: 50nV/√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.

3.9µA, SC70-3, 30ppm/°C Drift Voltage References

REF3312, REF3318, REF3320, REF3325, REF3330, REF3333

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **REF3312**, **REF3318**, **REF3320**, **REF3325**, **REF3330**, or **REF3333**)

Key Features

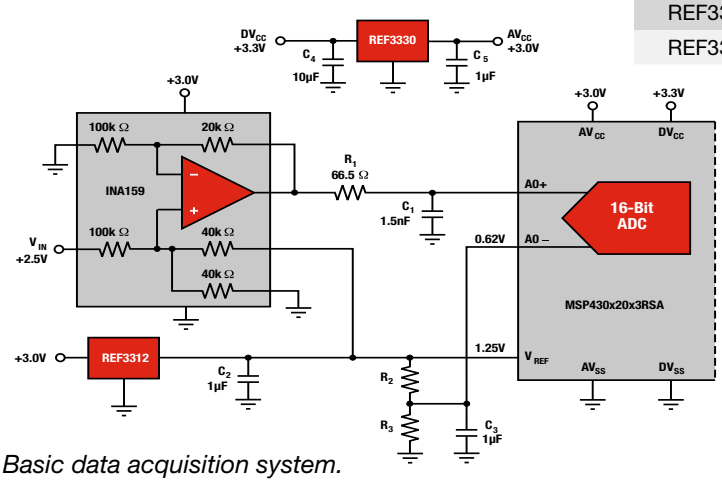
- Low power: Iq = 3.9µA (typ)
- High initial accuracy: 0.15% (max)
- Low dropout (25mV at 25°C and 1mA I_{OUT})
- Robust output current drive: ±5mA
- ±30ppm/°C temp drift (max)
- Extended industril temp range: -40°C to 125°C

Applications

- Blood glucose meter
- Digital stethoscope
- Portable ECG/EEG

The REF33xx is a low-power, precision, low-dropout voltage reference family available in the tiny SC70-3 and SOT23-3 packages. Small size and low power consumption (5µA max) make the REF33xx ideal for a wide variety of portable applications.

Product	Voltage (V)
REF3312	1.25
REF3318	1.8
REF3320	2.048
REF3325	2.5
REF3330	3.0
REF3333	3.3
REF3340	4.096



Basic data acquisition system.

Consumer Medical General

1.8V, microPower CMOS Operational Amplifier Zerø-Drift Series
OPA333, OPA2333

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/OPA333** or **www.ti.com/sc/device/OPA2333**

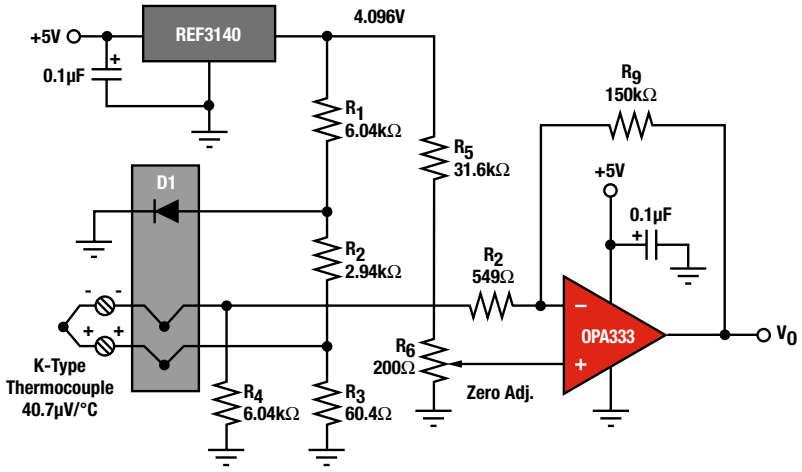
Key Features

- Low offset voltage: 10µV (max)
- Zerø drift: 0.05µV/°C (max)
- 0.01Hz to 10Hz noise: 1.1μV_{PP}
- Quiescent current: 17µA
- Supply voltage: 1.8V to 5.5V
- Rail-to-rail input/output
- Packaging: SC70, SOT23
- EMI input-filtered

Applications

- Medical instruments
- Temperature measurements
- Battery-powered medical instruments
- Electronic weigh scales
- Patient monitoring

The OPA333 series of CMOS operational amplifiers uses a proprietary auto-calibration technique to simultaneously provide very low offset voltage (10µV max) and near-zero drift over time and temperature. These miniature, high-precision, low quiescent current amplifiers offer high-impedance inputs that have a common-mode range 100mV beyond the rails and rail-to-rail output that swings within 50mV of the rails. Single or dual supplies as low as +1.8V (±0.9V) and up to +5.5V (±2.75V) may be used. The OPA333 family offers excellent CMRR without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.



OPA333 in temperature measurement circuit.

System Support Products

Voltage Level Translation

Applications

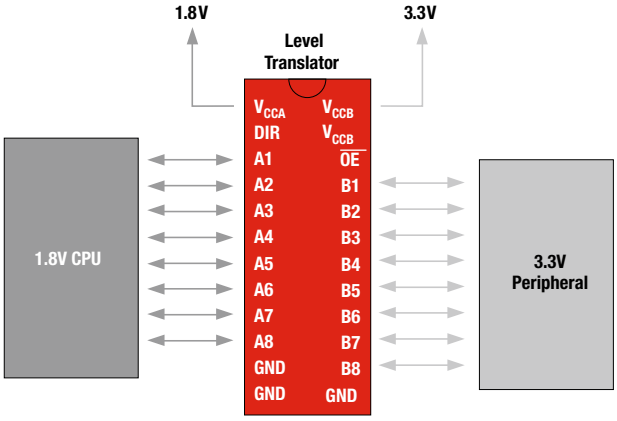
- LCD interface
- Interface devices with different supply voltages

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.

Audio Signal Routing

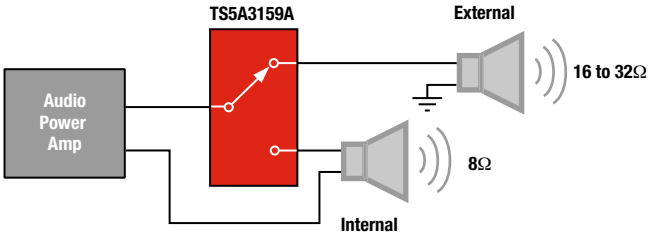
Applications

- DeMUX internal/external speakers
- MUX audio power amplifier
- Low-power routing (<100mA)
- Amplifier gain adjustment

One of the most common applications for analog switches is signal routing. Routing may come from one source to multiple destinations or from several sources to a single destination. A single-pole, double-throw analog switch can be used for either situation. The switch could be used to reroute the output of the audio power amplifier to two different speakers. Another common application is switching from an audio amplifier in the baseband of a mobile handset to an audio power amplifier for higher power output.

Suggested Components

Component	Configuration	V+ (V)	r_{on} (Ω)	Smallest Footprint Pins/Packages
TS5A3159A	1 x SPDT	1.65 to 5.5	0.9	6/WCSP
TS5A3166	1 x SPST	1.65 to 5.5	0.9	6/WCSP
TS5A23166	2 x SPST	1.65 to 5.5	0.9	6/WCSP
TS5A3153	1 x SPDT	1.65 to 5.5	0.9	8/WCSP
TS5A6542	1 x SPDT	1.65 to 5.5	0.75	8/WCSP
TS5A23159	2 x SPDT	1.65 to 5.5	0.9	10/Micro QFN
TS5A26542	2 x SPDT	1.65 to 5.5	0.75	12/WCSP
TS5A3359	1 x SP3T	1.65 to 5.5	0.9	8/WCSP



Example application block diagram.

System Support Products

I²C Bus I/O Expansion and LED Drivers

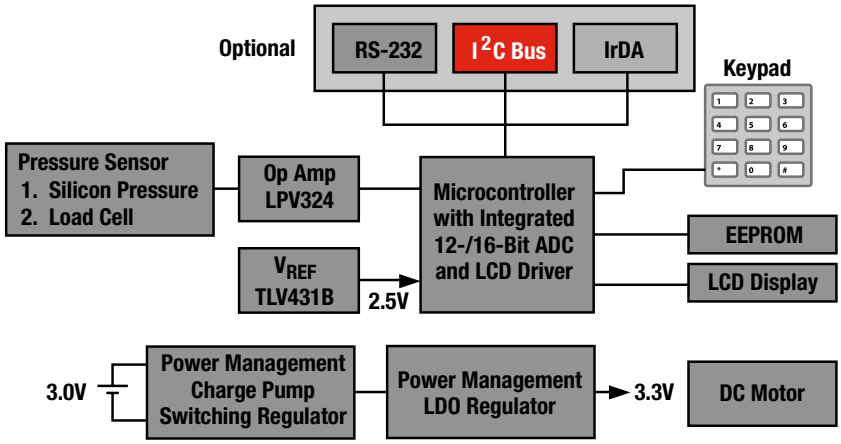
Benfits

- Processor pin savings
- Improved board routing
- Reduced board space

Applications

- Keypad control
- LED control
- Temperature sensing

I²C I/O expanders and LED drivers supplement application functionality. They free the processor from less critical functions and serve to create a more efficient design. Often there are not enough GPIOs available on the microcontroller to control all of the desired peripherals, such as interfacing to a keypad. An I²C bus expander can increase the number of GPIOs in the application while taking up minimal board space. I²C LED drivers free the processor from LED blink operations.



Example application block diagram.

Suggested Components

Device	Max freq. (kHz)	No. of I/Os	I²C address	V_{CC} range (V)
Low–Voltage I/O Expanders				
TCA6408A	400	8	0100 00x	1.65 to 5.5
TCA6416A	400	16	0100 00x	1.65 to 5.5
TCA6424	400	24	0100 00x	1.65 to 5.5
TCA9535	400	16	0100 xxx	1.65 to 5.5
TCA9539	400	16	1110 1xx	1.65 to 5.5
TCA9555	400	16	0100 xxx	1.65 to 5.5
I/O Expanders				
PCA6107	400	8	0011 xxx	2.3 to 5.5
PCA9534	400	8	0100 xxx	2.3 to 5.5
PCA9534A	400	8	0111 xxx	2.3 to 5.5
PCA9535	400	16	0100 xxx	2.3 to 5.5
PCA9536	400	4	1000 001	2.3 to 5.5
PCA9538	400	8	1110 0xx	2.3 to 5.5
PCA9539	400	16	1110 1xx	2.3 to 5.5
PCA9554	400	8	0100 xxx	2.3 to 5.5
PCA9554A	400	8	0111 xxx	2.3 to 5.5
PCA9555	400	16	0100 xxx	2.3 to 5.5
PCA9557	400	8	0011 xxx	2.3 to 5.5
PCF8574	100	8	0100 xxx	2.5 to 6.0
PCF8574A	100	8	0111 xxx	2.5 to 6.0
PCF8575	400	16	0100 xxx	2.5 to 5.5
PCF8575C	400	16	0100 xxx	4.5 to 5.5
LED Driver				
TCA6507	400	7	1000 101	1.65 to 3.6
Keypad / Keyboard Controller				
TCA8418	1000	18	110100	1.65 to 3.6

System Support Products

System-Level ESD/EMI Protection for High-Speed Applications

Benefits

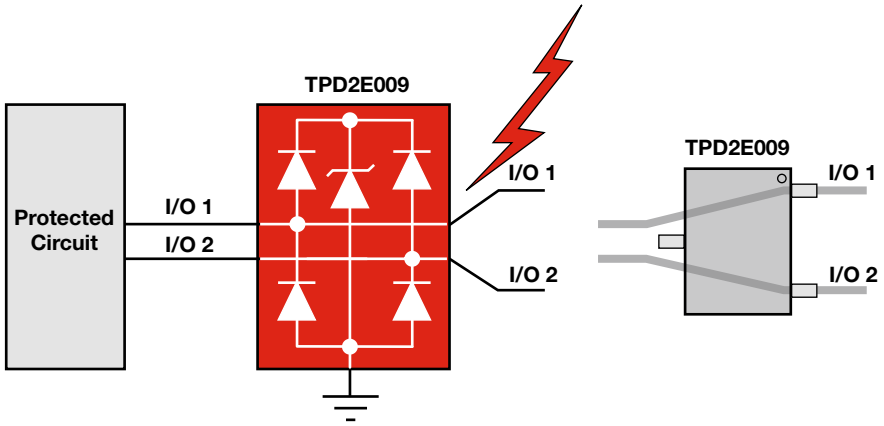
- System-level ESD protection for high-speed interconnects
- Space-saving package and flow-through layout enable glitch-free layout for the high-speed portable applications
- Ultra-low 1nA leakage current enables precision analog measurements like those of glucose meters
- The optional V_{CC} pin allows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

**For additional product information see designated page number.*
To view more system block diagram compatible products, visit ***www.ti.com/medical***

Power Management for Consumer Medical

Low-I_Q LDO with Dual-Level Outputs
TPS78001

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/TPS78001**

Key Features

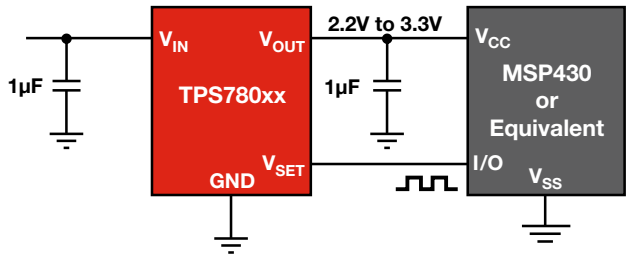
- Rated output current: 150mA
- Ultra-low I_Q: 500nA typ (TPS780xx)
- Input-voltage range: 2.2V to 5.5V
- Output voltages: Fixed (1.5V to 4.2V) and adjustable (1.22V to 5.25V)
- V_{SET} pin allows V_{OUT} to toggle between two factory EEPROM preset values
- Stable with 1µF ceramic output capacitor
- Packaging: TSOT23-5, 2 x 2mm SON

Applications

- TI MSP430™ attach applications
- Wireless handsets
- Portable media players

The TPS780xx family of low-dropout (LDO) regulators offers the benefits of ultra-low power (I_Q = 500nA), miniaturized packaging (2 x 2mm SON-6), and selectable dual-level output-voltage levels. An adjustable version is also available but does not have the capability to shift voltage levels.

The V_{SET} pin allows the end user to switch between two voltage levels on the fly through a microprocessor-compatible input. This LDO is designed specifically for battery-powered applications where dual-level voltages are needed. With ultra-low I_Q (500nA), this device is ideal for applications such as microprocessors, memory cards and smoke detectors.



TPS780xx with integrated dynamic voltage scaling.

0.7V_{IN} Boost Converter with 5µA I_Q
TPS61220

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

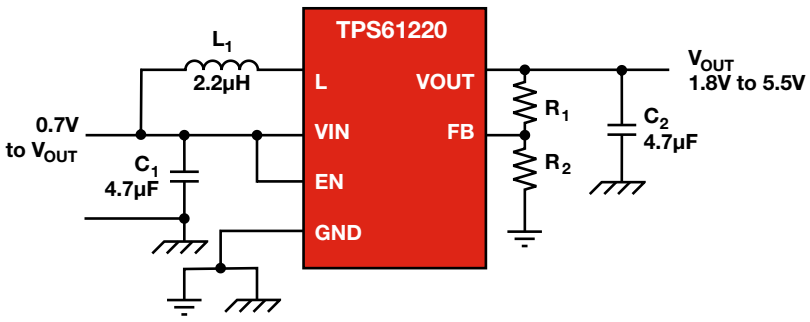
Key Features

- 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 micro-controllers 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, 2 x 2mm SC-70 package.



TPS61220 boost converter with low I_Q.

Power Management for Consumer Medical

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**

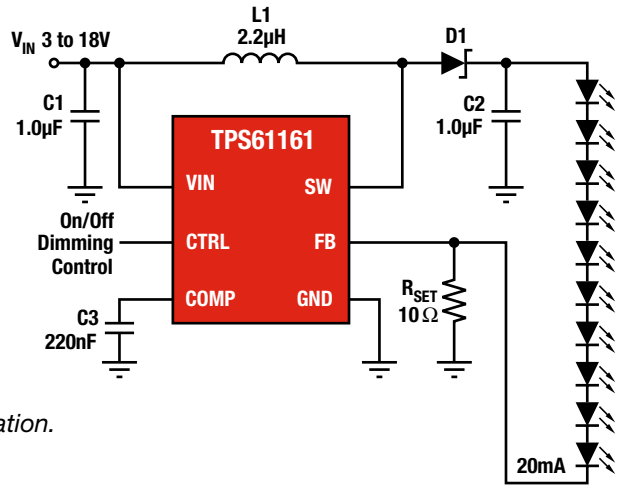
Key Features

- 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: 2 x 2 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**

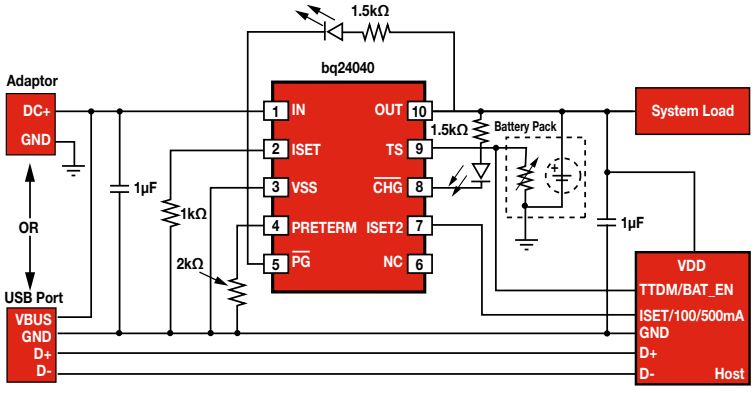
Key Features

- 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, 2-mm x 2-mm 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 for Consumer Medical

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, 2.5 x 4mm SON

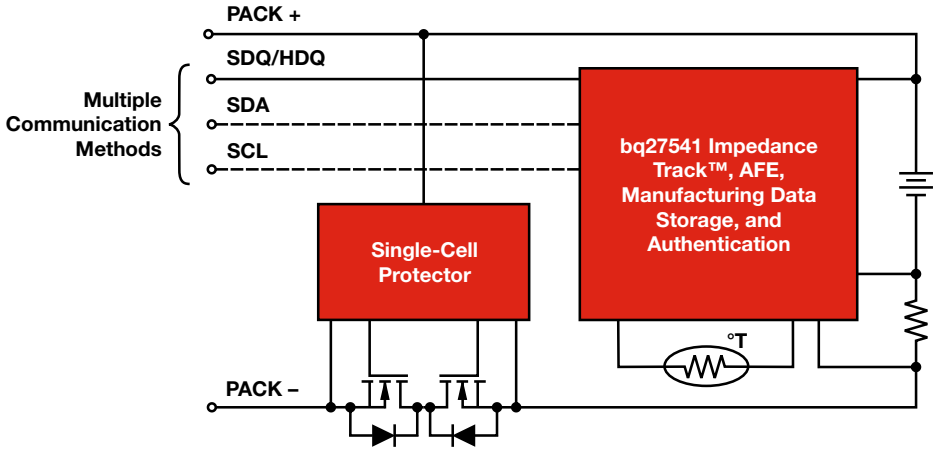
Applications

- 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.

Component Recommendations

Amplifiers

Component	Description	Key Features	Benefits	Other TI Solutions
INA118	Instrumentation Amp	55µV offset, 0.7µV/°C drift, 10nV/√(Hz) noise	Low drift, low noise, wide supply	INA128, INA326, INA333
INA122	Instrumentation Amp	±50µV (max) input offset, 83dB CMRR, 0.06mA (typ) I_Q	Low power, wide supply, CM to Gnd	INA122: INA121, INA126, INA128
INA333 **Page 11*	Instrumentation Amp	25µV (max) offset, 50nV/°C drift, 50µA (typ) Iq	Best offset/noise combination, supply down to 1.8V, low power	INA321, INA326, INA118
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
OPA333/2333 **Page 12*	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**
OPA364	CMOS Amplifier	1.8V, 7MHz, 90dB CMRR, 5V/µs slew rate, 750µA/ch I_Q	Sensor amplification in battery-powered systems	OPA363, OPA2363, OPA2364, OPA4364
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
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
OPA2889	Low-Power High-Speed Amp	Typical quiescent current of 460µA/channel	Supports portable and power-sensitive applications	OPAx890, OPAx684, OPAx683, THS4281
THS4524	Very Low-Power Differential Amp	SAR and ΔΣ drivers, 145MHZ, 490V/µs slew rate	Accurate output common-mode	
TLV276x	microPower Op Amp	1.8V, RRIO, 500µV input offset voltage, 500kHz BW	Available in S, D, Q, 20µA/ch IQ	
TPA2011D1	Analog-Input Class-D Amp	Variable gain, 3.2W mono Class-D with integrated DAC noise filter in 0.4mm pitch WCSP	The TPA2011D1 Class-D speaker amplifier is smaller, has fewer external components, consumes less power and has no pop	TPA2010D1
TPA2013D1	Analog-Input Class-D Amp	2.7W constant output power, mono, Class D, integrated boost converter	Louder audio at low battery levels	TPA2014D1
TPA2026D2	Analog-Input Class-D Amp with AGC/DRC	3.2-W/channel, stereo Class-D audio amplifier with fast gain ramp, SmartGain™ AGC and DRC	Provides louder and clearer audio while protecting speakers using DRC and AGC compared to competitive products using just the AGC limiter option	TPA2016D2, TPA2017D2
TPA2028D1	Analog-Input Class-D Amp with AGC/DRC	3.0-W mono Class-D audio amplifier with fast gain ramp, SmartGain™ AGC and DRC	Provides louder and clearer audio while protecting speakers using DRC and AGC compared to competitive products using just the AGC limiter option	
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	
Data Converters				
ADS1115	Delta-Sigma ADC, I²C	16-bit, 860SPS, 4 SE, 2 diff input, PGA, MUX, comparator, V_{REF}	Smallest 16-bit ADC, 2.0 x 1.5 x .04 mm leadless WFN pkg; reduces system size/component count	**ADS1113/4, ADS1013/14/15**
ADS7866	SAR ADC, Serial	1.2V, 12-bit, 200kSPS (max), 85dB SFDR	Very small, low power	ADS7888
ADS7924	microPower SAR ADC	12-bit, 100kSPS, 4 channel, ≤1µA power down current, I²C interface, QFN package	Intelleigent system power management and self monitoring	
ADS8201	Low-Power SAR ADC	8 channel, 12-bit, 100kSPS, 1.32mW power consumption at 100kSPS	Full on-chip data acquisition system	ADS7870
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
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
DAC7551	V_{OUT} DAC	12-bit, 500kSPS, ±0.5LSB DNL, ±1LSB INL, 0.27mW power	Ultra-low glitch	DAC7554
DAC8534	V_{OUT} DAC	16-bit, 0.093MSPS, ±1LSB DNL, ±64LSB INL, 2.7mW power	Quad	
DAC8554	Low-Power DAC	16-bit, 1-4 chs, ±3 LSB (typ) INL, 0.1 to 0.15nV-s glitch	Excellent AC/DC performance	DAC8564, DAC8534
DAC8551	V_{OUT} DAC	16-bit, 140µA at 2.7V operation, 0.1nV-s glitch energy	Very low power, ultra-low glitch	DAC8531
DAC8560	V_{OUT} DAC	16-bit, 2ppm/°C temp drift, 2.5V int reference	Tiny package, single channel	DAC8564, DAC8565
DACx311	Low-Power DAC	14-and 16-bit, 1.8V to 5.5V, 80mA, 14- and 16-bit, low-power, single-channel in SC70 package	Easy resolution upgrade and downgrade capability; decrease board space and power requirements	
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	TLV320AIC3104, TLV320AIC3120
References				
REF29xx	Low-Power, Low-Cost Series Reference	50µA, 2% initial accuracy, 100ppm/°C max drift, ±25mA output, 1.25V, 2.048V, 2.5V, 3.0V, 3.3V, 4.096V		REF30xx, REF31xx, REF33xx
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

**For additional product information see designated page number*

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

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

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
References (Continued)				
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	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 **Page 11*	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	Precision Reference	0.05% accuracy, 3ppm/°C (max) drift, 3μV_{PP}/V low noise, 2.048V, 2.5V, 3.0V, 4.096V, 4.5V, 5V, 10V	Outstanding accuracy	REF02, REF102
Processors				
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	
MSP430F24xx	Ultra-Low-Power 16-Bit MCU	32 to 120KB Flash, 2 to 8KB RAM, SPI + I^2C + UART, DMA, SVS	8 ch. 12-bit ADC, 2 ch.12-bit DAC, analog comp, HW multiplier	
MSP430F26xx	Ultra-Low-Power 16-Bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART, DMA, SVS	8 ch. 12-bit ADC, 2 ch.12-bit DAC, analog comp, 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, 2 op amps	5 ch. 16-bit SD ADC, 12-bit DAC	
MSP430FG42x0	Ultra-Low-Power 16-Bit MCU	16 to 32KB Flash, 256B RAM, 56 segment LCD 2 op amps	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	
MSP430FG43x	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 1KB/2KB RAM, SPI + UART, SVS, 128 segment LCD, 3 op amps	12 ch. 12-bit ADC, 2 ch. 12-bit DAC, DMA, 3 op amps	
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	
MSP430FG461x	Ultra-Low-Power 16-Bit MCU	92 to 120KB Flash, 4KB/8KB RAM, SPI + I^2C + UART/LIN + IrDA, 160 LCD, 3 op amps	12 ch.12-bit ADC, 2 ch.12-bit DAC, A-comp, 3 op amp, HW multiplier	
MSP430FG47x **Page 9*	Ultra-Low-Power 16-Bit MCU	32 to 60KB Flash, 2KB RAM, 16-bit ΔΣ A/D, 12-bit D/A, op amp, 128Seg LCD	Two 16-bit timers, a basic timer with a real-time clock, a high performance 16-bit ΔΣ ADC, dual 12-bit DACs, two configurable op amps	
MSP430F54xxA **Page 10*	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	
MSP430F552x	Applications Processor	Up to 128KB Flash, 8+2KB RAM, USB, SPI + I^2C	Integrated USB, 12-bit ADC	
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
TMS320C5000™	DSP	Power efficient, high performance	Fixed-point DSP with industry's best combination of standby and dynamic power consumption	
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
TMS320VC5506	DSP	200MHz, dual MAC, very low standby power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320VC5509A, TMS320VC5502
Interface				
TPD3E001 **Page 15*	3-Bit/Single-Channel USB OTG ESD	1.5pF cap, 1nA leakage	Low capacitance, small package	TPD2E001, TPD4E001
TPD4S012 **Page 15*	4-Bit/Single-Channel ESD with V_{BUS} Clamp	USB HS ESD with additional V_{BUS} clamp	Replace one additional component for USB charger application	TPD4S014

For additional product information see designated page number. To view more system block diagram compatible products, visit* ***www.ti.com/medical*

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

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Interface (Continued)				
TPD4E004 *Page 15	4-Bit/2-Channel	1.6pF cap, low DC breakdown voltage	Low capacitance, small package	TPD6E004
TPD4E002 *Page 15	4-Bit/2-Channel	USB FS	Very robust ESD (15kV contact)	
TUSB3410	USB 2.0 Full-Speed to Enhanced Serial Port Bridge	USB 2.0 compliance, enhanced UART port		
TUSB1106	USB 2.0 Full-Speed Trans.	USB 2.0 compliance, level shifting, system-level ESD	Smaller package, no external ESD needed	TUSB1105, TUSB2551A
Power Management				
bq77PL900	5-10 Series Li-ion Battery Protection & 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	
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
bq24040 *Page 17	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.	
bq24081	Battery Charger	One-cell Li-Ion charger with 1-A FET, timer enable and temperature sensing	Great for space-limited charger applications	
bq27010	Battery Fuel Gauge	Li-Ion and Li-Pol battery gas gauge	Reports accurate time-to-empty of battery	bq27200, bq27500
bq27541 *Page 18	Battery Fuel Gauge	Li-Ion battery gas gauge with Impedance Track™ fuel-gauge technology	Reports accurate time-to-empty of battery	bq27510
TPS2041B	USB Power Switch	USB compliant power source, short circuit protection	USB switch with adjustable precision OC	TPS2550
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 1.8 V	Ultra-small, low quiescent current current limited switch	TPS22949, TPS22945
TPS2550	USB Power Switch	USB compliant power source, short circuit protection	USB switch with adjustable precision OC	TPS2551
TPS2551	Power Switch	Adjustable current limit, 100mA to 1100mA	Allows designer to precisely set current limit	TPS2051B, TPS2061
TPS61081	LED Boost Converter	Input to output isolation	Protection from short between any pins and between any pin to ground	TPS61161
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	
TPS61160/61 *Page 17	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 *Page 16	Boost Converter	Low Input Voltage, 0.7V boost converter with 5.5µA quiescent current	Can be switched off to minimize battery drain; small package solution	
TPS62230	Step-Down Converter	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62300	Step-Down Converter	500mA, 3MHz synchronous step-down converter	Very small inductor and high efficiency	TPS62040
TPS63030	Buck-Boost Converter	1-A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
TPS717xx	Low-Noise Single-Channel LDO	High bandwidth, very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS799xx
TPS718xx-yy	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719xx-yy
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low I_Q 500nA	DVS voltage designed to operate with MSP430™ to increase power savings	TPS781xx
TPS78001 *Page 16	Single-Channel LDO	Dual-level, fixed output voltages, ultra-low I_Q	Adjustable V_{OUT} for optimal performance, longer battery life	TPS717xx, TPS739xx
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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

**For additional product information see designated page number.*

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

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
RF ICs (Continued)				
RF Transceivers (Continued)				
TMS37157 **Page 8*	Passive Low Frequency Interface Device (PaLFI) With EEPROM and 134.2 kHz Transponder Interface	Ultra-low-power consumption, 2V to 3.6V supply voltage, low frequency HDX interface	It is the ideal device for any data logger, sensor or remote control application enabling operation without the need of a battery.	
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/1111	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	Second Generation 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
CC2540	2.4 GHz *Bluetooth*® low energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	Fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	

**For additional product information see designated page number.*

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

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

Diagnostic, Patient Monitoring and Therapy

Overview

Trends in Medical Diagnostic, Patient Monitoring and Therapy equipment include portability, connectivity, flexibility and system intelligence.

Medical 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. On top of this the precision of the sensor signal chain combined with the processing power of today's embedded processors have paved the way for these instruments to not only notice the smallest perturbation from normality in a signal, these devices can collect and process trends against large databases and even suggest a course of action.

These improvements in reliability, battery storage capability and usability have also taken the Automated External Defibrillators (AEDs) from equipment only found in medical facilities and emergency vehicles to tools deployed in many schools, businesses and other public areas. Low power processing allows an AED to sleep for long time periods, only waking up to run diagnostics, and then quickly get to full operation when needed. Such as the intelligence to guide the user safely through its use and the ability to sense if the pads are incorrectly placed on the patient have truly helped drive the proliferation of these devices.

By combining the advances in monitoring capabilities with those seen in motor control, power management, and control systems, applications such as ventilation/CPAP, dialysis, and infusion pumps have been made smaller, safer and less expensive. This trend has made it practical for CPAP systems and Infusion pumps to be placed in the home, and dialysis therapy to move from a hospital-only application to a doctor's office.

Connectivity for portable medical applications has become critical as consumers and caregivers are requiring data to move from medical devices to data hubs such as computers and mobile phones. TI is a promoting member of the Continua Health Alliance and now offers the first Continua-certified USB platform for Agent Devices. *See page 142 for more information.*

Continua® HEALTH ALLIANCE

For more information on TI's offering for Diagnostic, Patient Monitoring and Therapy, please visit *www.ti.com/patientmonitoring*

Digital Stethoscopes

The main elements of a digital stethoscope (see page 24) are the sensor unit that captures the heart and lung sounds (also known as auscultations), along with auscultation digitization and digital processing for noise reduction, filtering and amplification. Algorithms for heart rate detection and heart defect detection may also be included.

Power and battery management are key in this ultra-portable diagnostic tool. Design considerations include ultra-low-power consumption and high efficiency, both of which are driven by the need for extended battery life. The design must also incorporate high precision with a fast response time to allow quick determination of the patient's health status.

The need to record auscultations calls for cabled or wireless interfaces that transmit the auscultations. To enable ease-of-use, features like touch-screen control and display backlighting are essential. Adding these features without significantly increasing power consumption is a huge challenge.

TI's portfolio of processors, instrumentation and buffer amplifiers, power and battery management, audio codecs, and wired and wireless interface devices provides the ideal tool box for digital stethoscope applications.

The common core sub-systems of a digital stethoscope are the analog front-end/sensor interface and codec, low-power processor, and data storage and transmission.

Digital Stethoscopes

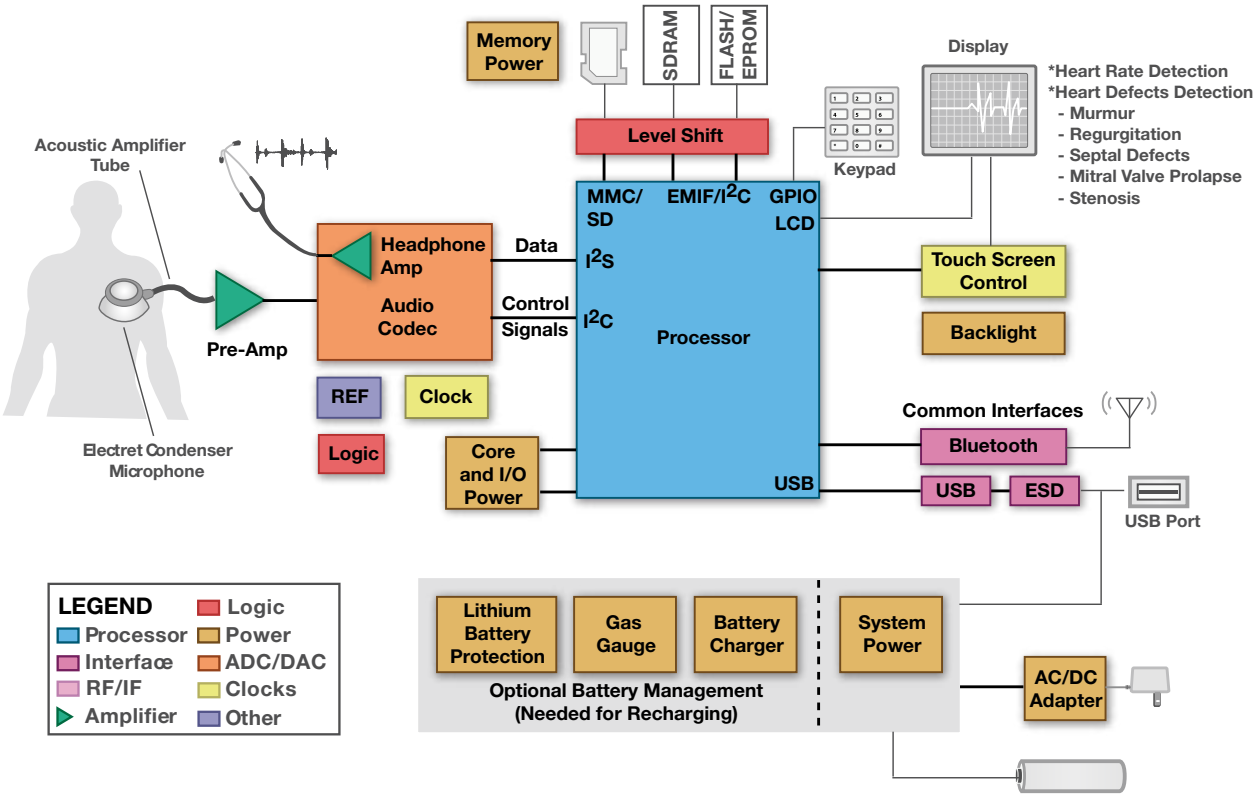
Analog Front-End/Sensor Interface and Codec

Auscultation signal input is amplified and digitized by the audio codec. Auscultations signals after being digitized are subjected to signal processing. They are then converted to analog and sent to the stethoscope earpiece.

Low-Power Processor

Processors that are able to execute the digital stethoscope's signal processing functions, such as noise reduction, algorithms for heart rate detection and heart defect detection, while maintaining a very low constant current draw from the battery, are a good fit.

The ability to control memory interfacing and peripheral devices is also helpful. Processors that manage the digital display and keyed functions allow auscultation waveforms to be displayed and manipulated without additional components.



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 stethoscope system block diagram.

Digital Stethoscopes

Power-Efficient Fixed-Point DSP

TMS320C5515

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320C5515**

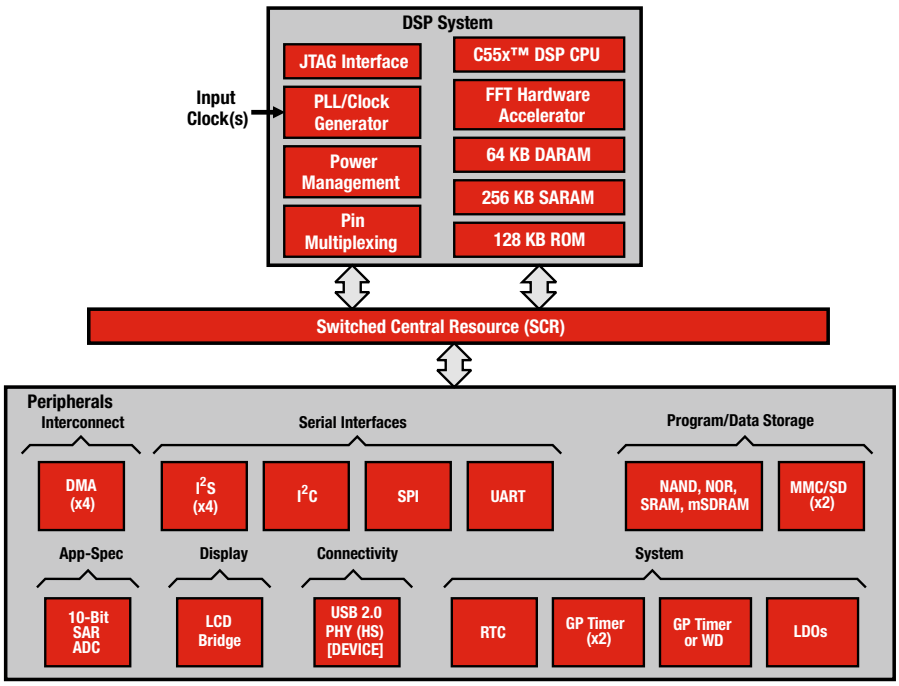
Key Features

- High-performance/low-power, C55x™ fixed-point DSP
  - 16.67/13.33/10/8.33ns instruction cycle time
  - 60, 75, 100, 120MHz clock rate
- 320K bytes on-chip RAM
- 16-/8-bit external memory interface (EMIF)
- Two multi-media card/secure digital I/Fs
- Serial-port I/F (SPI) with four chip-selects
- Four inter-IC sound (I^2S bus™)
- USB 2.0 full- and high-speed device
- LCD bridge with asynchronous interface
- Tightly-coupled FFT hardware accelerator
- 10-bit 4-input SAR ADC

Applications

- Portable ultrasound
- Automatic external defibrillator (AED)
- Electrocardiogram (ECG)
- Digital stethoscopes
- Cochlear implants

The TMS320C5515 is a member of TI's TMS320C5000™ fixed-point digital signal processor (DSP) product family and is designed for low-power applications. 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 DSP block diagram.

Digital Stethoscopes

Digital Stethoscope (DS) Analog Front End Module for the C5515 DS Medical Development Kit
TMDXMDKDS3254

Get samples, datasheets and evaluation modules at: **www.ti.com/tmdxmdkds3254**

Key Features

- DS AFE module key components
  - TLV320AIC3254: flexible, low-power, low-voltage stereo audio codec with programmable inputs and outputs
  - OPA335: 0.5µV/°C, CMOS zero-drift operational amplifier
- DS MDK system features
  - Based on industry's lowest power DSP processor – TMS320C5515
  - Audio output in three selectable modes:
    - Bell mode (20Hz to 220Hz)
    - Diaphragm mode (50Hz to 600Hz)
    - Extended Range (20Hz to 2000Hz)
  - Three channel input options, two condensor and one contact microphone
  - Volume control and mute
  - Real time display of heart signal on onboard LCD and PC
  - Store and playback option on PC side

Applications

- Digital stethoscope devices
- Patient monitoring

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 TMDXMDKDS3254 Digital Stethoscope (DS) Analog Front End (AFE) module consists of the DS AFE module, a processor board (C5515 DSP evaluation module), a set of collateral and C5515-based application sample code to implement the DS application. The DS MDK delivers a complete signal chain solution to enable developers to build an entire DS system quickly for evaluation and get to production faster.

TMDXMDKDS3254 EVM.

Digital Stethoscopes

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
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
TMS320C5505	Low-Power DSP	16-/8-bit EMIF, 320K bytes on-chip RAM, USB 2.0 full- and high-speed device	High-performance, low-power	
TMS320C5515 *Page 25*	Power-Efficient DSP	16-/8-bit external memory interface, 320K bytes on-chip RAM, USB 2.0 full- and high-speed device	Designed for low-power applications; low-power, high-performance	
TMS320VC5503	Low-Power DSP	Up to 200MHz, dual MAC, 16-bit HPI, 3 McBSP	Power efficient, low-cost DSP, C55x™ code compatibility	C550x DSP
TMS320VC5507	Low-Power DSP	Up to 200MHz, dual MAC, 128KB RAM/64KB ROM, USB 2.0 full speed, 10-bit ADC	Power efficient, C55x code compatibility	C550x DSP
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
Data Converters				
TLV320DAC32	Low-Power Audio DAC	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		
TLV320AIC3104	Low-Power Audio Codec	Low-power stereo codec, 6 inputs, 6 outputs, headphone amp, enhanced digital effects		
TLV320AIC3106	Low-Power Audio Codec	Low-power stereo codec, 6 inputs, 6 outputs, headphone amp, enhanced digital effects		
TLV320AIC3254	Low-Power Audio Codec	Very-low power, single supply, miniDSP for audio processing	Longer battery life, better audio quality, lower system cost	TLV320AIC3204 (pin to pin without miniDSP)
Amplifiers				
DRV134/5	Line Driver/ Receiver	0.0005% at f = 1kHz distortion, 17V_{rms} into 600Ω output swing, ±5.2mA I_Q, ±4.5V to ±18V supply	Balanced output pair, low distortion	INA134, INA137
INA134/2134	Line Driver/ Receiver	0.0005% at f = 1kHz distortion, 90dB CMRR, 0dB (1V/V) fixed gain, ±2.9mA I_Q, ±4V to ±18V supply	Excellent AC specifications, low distortion	INA137, OPA1632
INA137/2137	Line Driver/ Receiver	0.0005% at f = 1kHz distortion, 90dB CMRR, 6dB fixed gain, ±2.9mA I_Q, ±4V to ±18V supply	Differential line receiver, low distortion	INA134, DRV134
OPA134/2134	Audio Amp	0.00008% ultra-low distortion, 8nV/√Hz noise, 8MHz BW, 120dB open-loop gain, ±2.5V to ±18V supply	True FET-input stage, low distortion, low noise	OPA211, OPA604
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, OPA132
OPA209	Precision Op Amp	2.2nV/√Hz at 1kHz, ±4.5V to 18V supply, 18MHz, 2.5mA quiescent current (typ)	Unity gain stable, RRO, wide supply range, low power	
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
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
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,
THS4521	Low Power FDA	1.14mA quiescent current (typ), 4.6nV/√Hz voltage noise	Very low power, low noise enables high accuracy	
Interface				
TPD2E001	ESD Solution	Low capacitance, 2 channels, ±15kV ESD-protection array for high-speed data interfaces	IEC 61000-4-2 system level (level 4) ESD protection; low input capacitance in space-saving packages	SN65220

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

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

Digital Stethoscopes

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management				
bq29312A	Li-Ion Battery Protection IC	Provides under- and overvoltage, overcurrent, short-circuit and overtemperature protection	Provides primary safety protection for cells	
bq29330	Battery Safety	Battery pack full-protection analog front end	Provides individual cell voltages and battery voltage to battery-management host	
bq29410/1/2	Li-Ion Battery Protection IC	Provides overvoltage protection for Li-Ion and poly cells	Prevents false triggers during dynamic operating conditions	
bq2000	Battery Management	Multi-chemistry charger	One charge for both Li-Ion and NiCad/NiMH cells	
bq24100	Battery Charge Management	Switch mode, 1100kHz switching frequency, >2A charge current	d/dt, min current primary charge termination method	
TPS5130	DC/DC Converters	Triple synchronous buck controller with LDO	Provides 4 output voltages in 1 package	
TPS61070	DC/DC Converters	600mA switch low voltage in boost	Can generate 5V rail from 1-, 2- or 3-cell alkaline or 1-cell Li-Ion	
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 Converters	Dual switcher boost and LDO	Compact 2-voltage solution	
TPS62202	DC/DC Converters	300mA synchronous	Ultra-small battery-powered solutions	
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
TPS65020	Linear Charge Management	6-channel power management IC with 3 DC/DCs, 3 LDOs, I^{2}C 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^{2}C interface and DVS, optimized for DaVinci™ DSPs	Provides complete DaVinci solution in one package	
TPS65800	Linear Charge Management	6-channel power management IC with 2 DC/DCs, 7 LDOs, I^{2}C interface and dynamic voltage scaling	Complete power management solution in one package	
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	
TPS79601	LDO	1A low-dropout regulator with high PSRR	Low-noise LDO stable with 1µF ceramic capacitor	TPS796xx
TPS79630	LDO	1A low-dropout regulator with high PSRR	Low-noise LDO stable with 1µF ceramic capacitor	TPS796xx
Toolkits				
TMDXMDKDS3254 **Page 26*	Digital Stethoscope (DS) Analog Front End Module for the C5515 DS Medical Development Kit	Audio output in three selectable modes; 3 channel input options; volume control and mute; real time display of heart signal on onboard LCD and PC; store and playback option on PC side	Based on industry's lowest power DSP processor – TMS320C5515	

**For additional product information see designated page number.*
To view more system block diagram compatible products, visit ***www.ti.com/medical***

Patient Monitoring

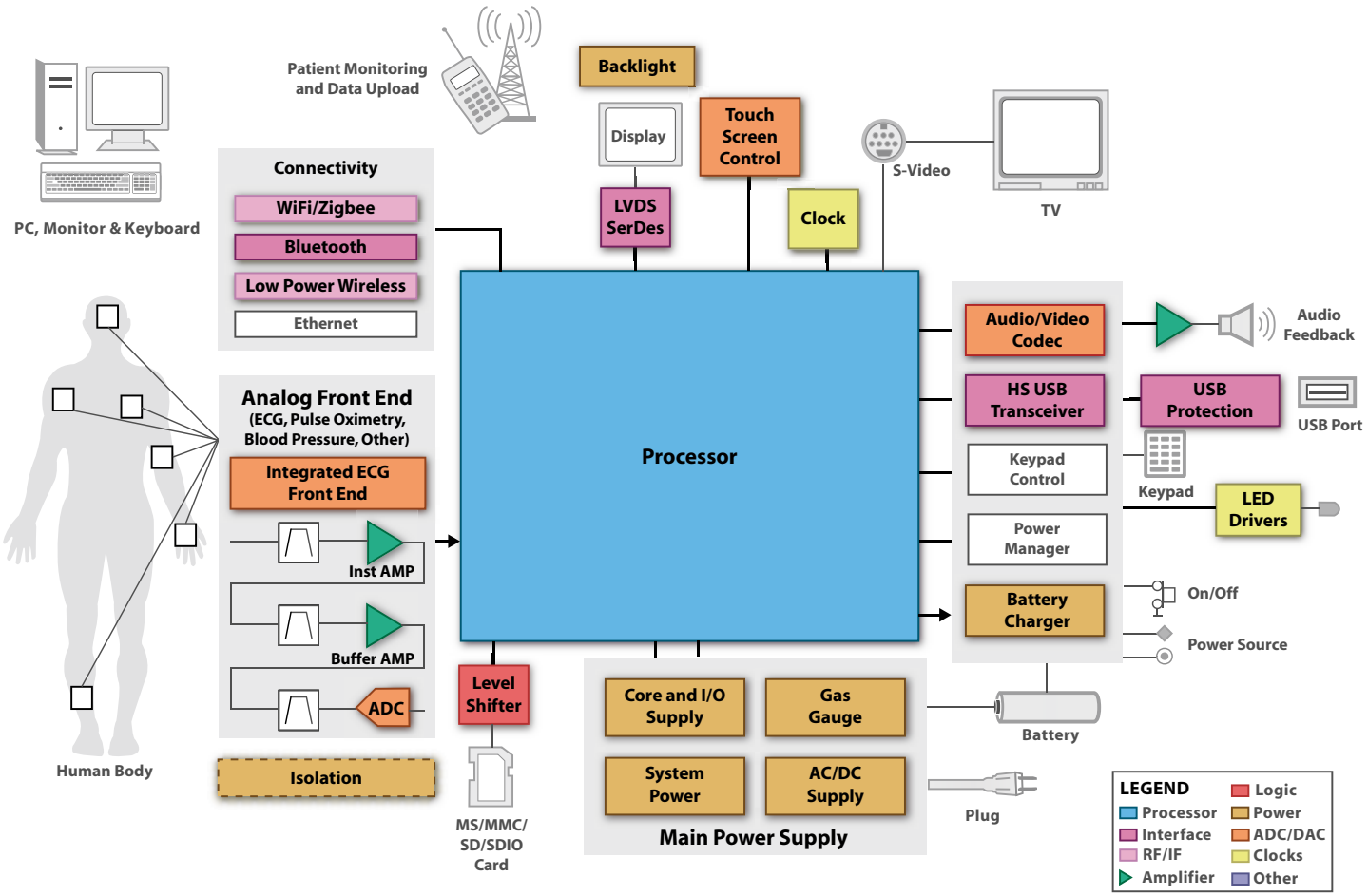
A variety of portable, single and multiple-parameter monitors have emerged over the last few years that measure blood pressure, glucose levels, pulse, tidal carbon dioxide and other biometric values. Patient monitors are portable, flexible devices that can be adapted to a wide range of clinical applications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

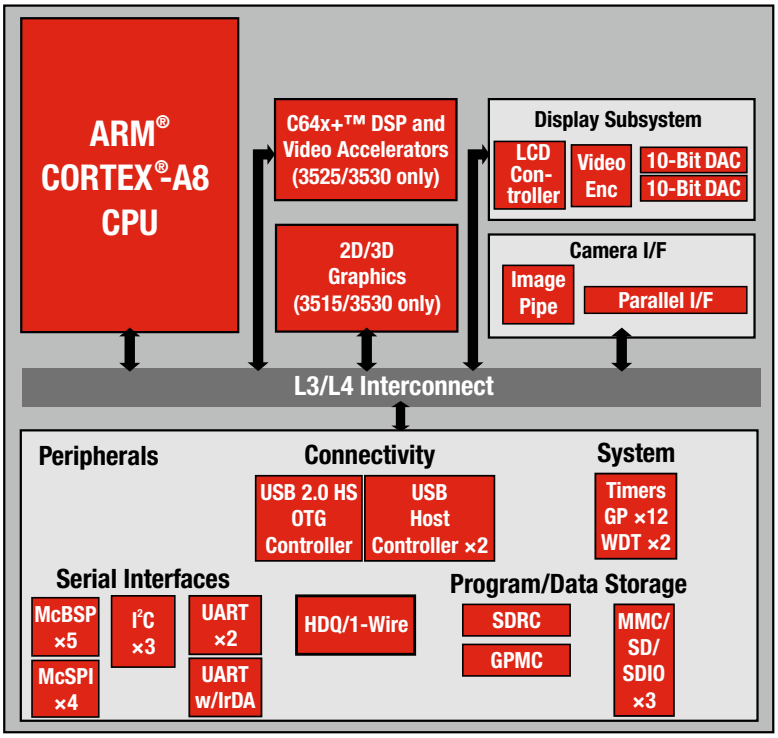
Key Features

- 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

Stellaris®

LM3S3xxx

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

Key Features

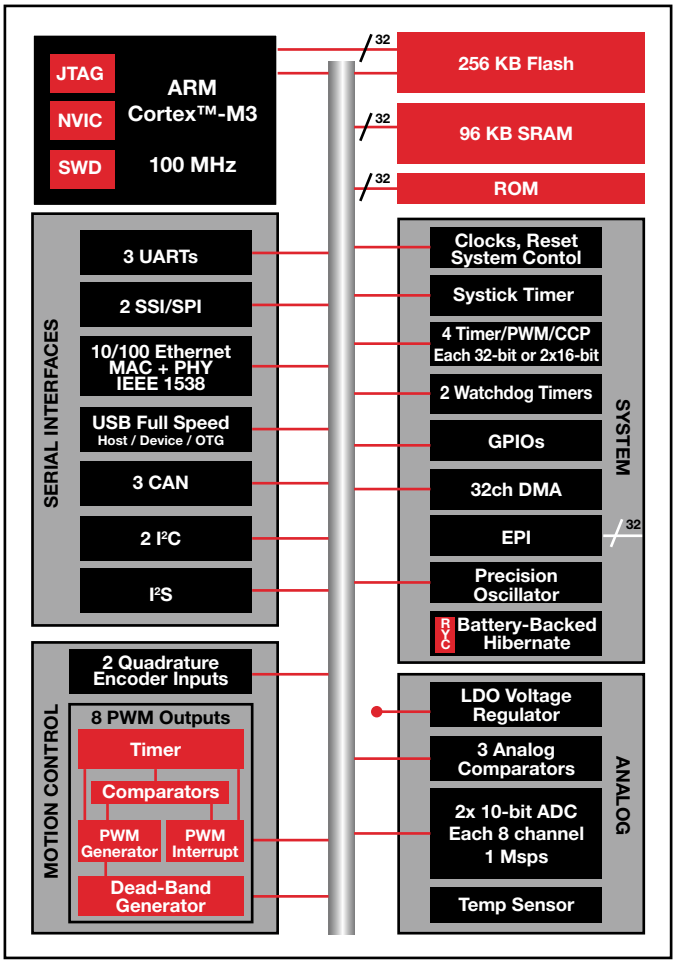
- Up to 256kB integrated flash and 96kB SRAM
- Integrated ethernet MAC+PHY
- USB host/device/on-the-go
- Free license for complete and rich software libraries (StellarisWare®)

Applications

- Patient monitoring
- Home health hubs

Designed for high-end microcontroller applications, the Stellaris family provides the entry into the industry's strongest ecosystem, with code compatibility ranging from $1 to 1GHz.

- Superior integration saves up to $3.28 in system cost
- Over 160 Stellaris family members to choose from
- Real MCU GPIOs—all can generate interrupts, are 5V-tolerant, and have programmable drive strength and slew rate control
- Advanced communication capabilities, including 10/100 Ethernet MAC/PHY, USB and USB OTG, CAN controllers, and extended peripheral interfaces
- Sophisticated motion control support in hardware and software
- Both analog comparators and ADC functionality provide on-chip system options to balance hardware and software performance
- Development is easy with the royalty-free StellarisWare software



Stellaris family block diagram.

Patient Monitoring

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics acelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
OMAP3530 **Page 30*	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
Stellaris® LM3S3xxx **Page 31*	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	
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 .04 mm 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
ADS7953	SAR ADC	12-bit, 16-channel, 1MSPS, SPI interface with threshold alarms, QFN package	Low power, small package, and excellent performance	**ADS7952, ADS7956, ADS7957/60/61**
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
TLV320AIC3254	Low-Power Audio Codec	Very-low power, single supply, miniDSP for audio processing	Longer battery life, better audio quality, lower system cost	TLV320AIC3204 (pin2pin without miniDSP)
TLV320DAC32	Audio DAC	Low-power stereo DAC, 4 outputs, HP/speaker amplifier, 3D effects		
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	
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2 to 500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency hopping systems	CC2500
CC1150	Sub-1GHz Transmitter	Programmable data rate from 1.2 to 500 kBaud, fast startup time (0.3µs), low current consumption	Fast development time and low system cost, flexible optimization of range vs. power, small solution size	

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

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

Patient Monitoring

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF ICs (Continued)				
RF Transceivers (Continued)				
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
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
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
CC2540	2.4 GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	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
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Fast-to-market *Bluetooth*® low energy compliant solution	
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	
Power Management				
bq2000/T	Battery Management	Multi-chemistry charger	One charge for both Li-Ion and NiCad/NiMH cells	
bq24100	Battery Charge Management	Switch mode, 1100kHz switching frequency, >2A charge current	d/dt, min current primary charge termination method	
TPS43000	DC/DC Controller	2MHz operation	Allows smaller-value inductor and input cap	
TPS5130	DC/DC Controller	Triple synchronous buck controller and LDO	Four outputs in one package allows smaller power solution	TPS65xxx
TPS61070	DC/DC Converter	Input voltage range of 0.9V to 5.5V	Allows 1-, 2- or 3-cell alkaline or 1-cell Li-Ion operation	
TPS61097-33	Boost Converter with Bypass Switch	Highly efficient, operates down to 0.3 V; bypass switch; 5nA shutdown current; SOT-23	Super efficient boost, works over entire battery range, low quiescent current, integrates the bypass switch, small package	
TPS61120	DC/DC Converter	Dual switch boost and 200mA LDO outputs	Highly efficient dual-output operation for 1-cell Li-Ion operation	
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 1.8 V	Ultra-small, low quiescent current current limited switch	TPS22949, TPS22945
TPS62420	DC/DC Converter	Dual step-down buck converter with 1-pin easy scale	Offers dynamic voltage scaling for power savings	
TPS62202	DC/DC Converter	300mA synchronous buck in a SOT-23 package	Ultra-small implementation	
TPS65020	Linear Charge Management	6-channel power management IC with 3 DC/DCs, 3 LDOs, I^{2}C 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^{2}C interface and DVS, optimized for DaVinci™ DSPs	Provides complete DaVinci solution in one package	
TPS65800	Linear Charge Management	6-channel power management IC with 2 DC/DCs, 7 LDOs, I^{2}C interface and dynamic voltage scaling	Complete power management solution in one package	
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	
TPS79601	LDO	1A low-dropout regulator with high PSRR	Low-noise LDO stable with 1µF ceramic capacitor	TPS796xx
TPS79630	LDO	1A low-dropout regulator with high PSRR	Low-noise LDO stable with 1µF ceramic capacitor	TPS796xx

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

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

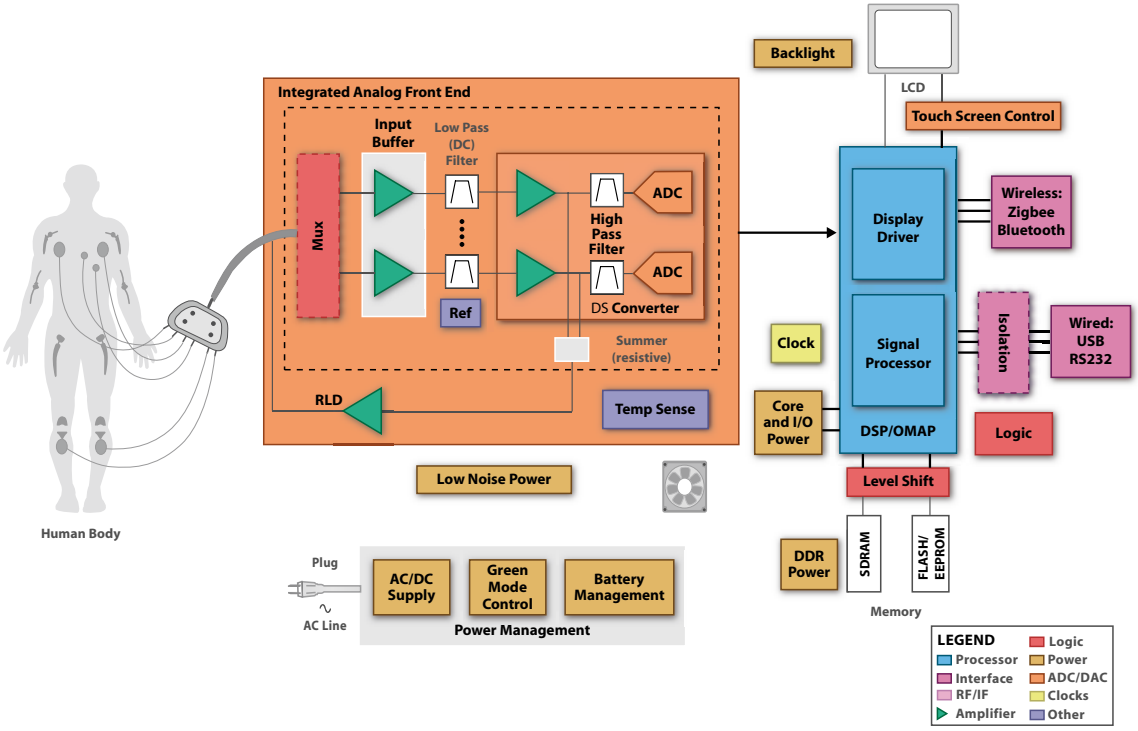
Biophysical Monitoring Overview

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 amplifier A2. Only a few microamps or less are required to achieve significant CMR improvement and stay within the UL544 limit.



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.

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

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

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.

Low-Power Applications Processor
OMAP-L137

Get datasheets, samples and technical documents at: **www.ti.com/sc/device/omap-l137**

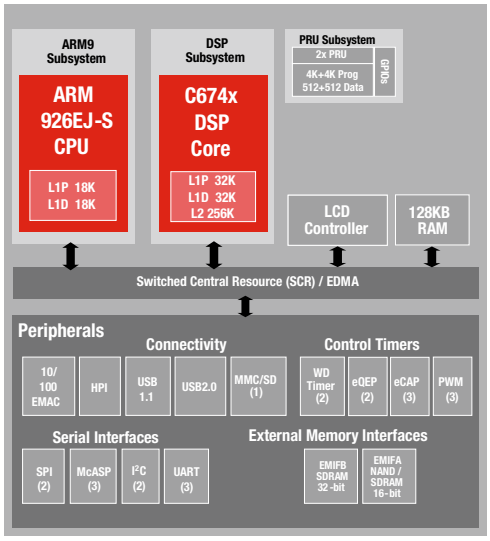
Key Features

- Dual core SoC
  - 300MHz ARM926EJ-S™ RISC MPU
  - 300MHz C674x VLIW DSP
- TMS320C674x fixed/floating-point VLIW DSP core
- Enhanced direct-memory-access controller 3 (EDMA3)
- 128K-byte RAM shared memory
- Two external memory interfaces
- Three configurable 16550 type UART modules
- LCD controller
- Two serial peripheral interfaces (SPI)
- Multimedia card (MMC)/secure digital (SD)
- Two master/slave inter-integrated circuit
- One host-port interface (HPI)
- USB 1.1 OHCI (Host) with integrated PHY (USB1)

Applications

- Medical measurement
- Industrial diagnostics

The OMAP-L137 is a low-power applications processor based on an ARM926EJ-S™ and a C674x DSP core. It consumes significantly lower power than other members of the TMS320C6000™ platform of DSPs. The OMAP-L137 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. The dual-core architecture of the OMAP-L137 provides benefits of both DSP and Reduced Instruction Set Computer (RISC) technologies, incorporating a high-performance TMS320C674x DSP core and an ARM926EJ-S core. 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.



OMAP-L137 block diagram.

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

Complete Analog Front End for ECG/EEG Applications

ADS1298

Get datasheets, samples and evaluation modules at: **www.ti.com/sc/device/ADS1298**

View the ADS1298 video at: **http://e2e.ti.com/videos/m/analog/134732.aspx**

Key Benefits

- Reduce components and board size by 95%
- 1mW/channel reduces solution power by 95%
- Single-chip solution increases system reliability and patient mobility

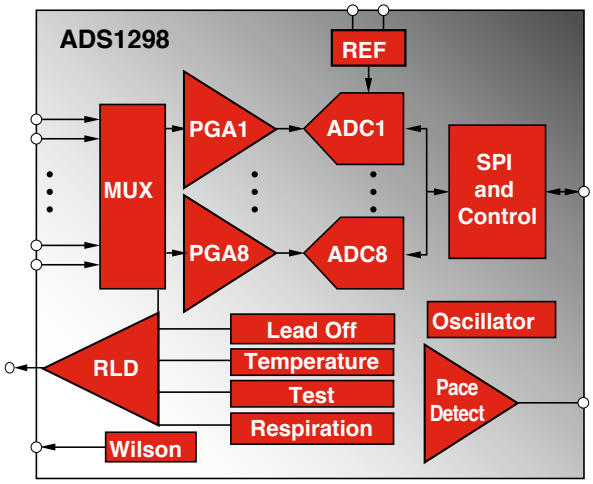
Key Features

- Eight low-noise PGAs
- Eight high-resolution, simultaneous sampling ADCs
- Integrated amplifier for right-leg drive
- Integrated amplifiers for Wilson Central Terminal (WCT) and Goldberger Central Terminals (GCT)
- Digital pace detection capability
- Continuous lead-off detection
- Onboard oscillator and reference for smaller footprint and low-power applications

Applications

- ECG and EEG applications

The eight-channel, 24-bit ADS1298 is the first in a family of fully integrated analog front ends (AFEs) for patient monitoring, portable and high-end electrocardiogram (ECG) and electroencephalogram (EEG). Succeeding four- and six-channel versions and 16-bit versions offer designers a migration path to varying resolutions and channel combinations for low-noise medical equipment. Examples include patient monitors, rest and stress ECG, fetal monitoring, hospital and public access AEDs, as well as sports and fitness monitors.



ADS1298 block diagram.

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

Low-Noise, 900kHz, 50µV, RRIO Precision Op Amps
OPA378, OPA2378

Get samples and datasheets at: **www.ti.com/sc/device/OPA378** or **www.ti.com/sc/device/OPA2378**

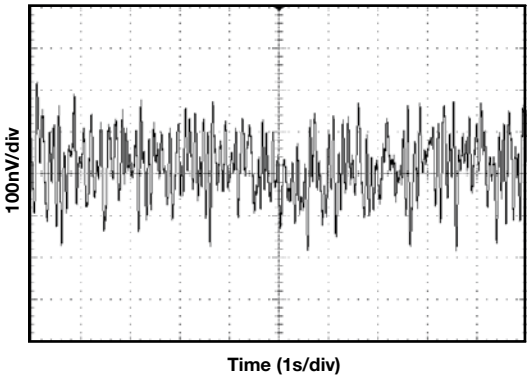
Key Features

- Low noise 0.1Hz to 10Hz: 0.4µV_{PP}
- Low offset voltage: 15µV (typ)
- Quiescent current: 125µA (typ)
- Offset drift: 0.1µV/°C (typ)
- Single-supply operation
- Supply voltage: 2.2V to 5.5V
- EMI input filters and RRIO
- Packaging: SC70-5, SOT23-5

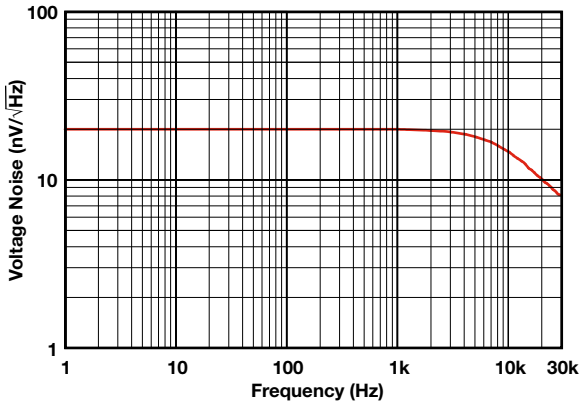
Applications

- Battery-powered instruments
- Medical instrumentation
- Temperature measurement
- Handheld test equipment

The OPA378 (single) and OPA2378 (dual) represent a new generation of micropower op amps featuring a combination of rail-to-rail I/O, low input offset voltage (50µV (max)), low quiescent current and 90kHz bandwidth. It has excellent PSRR which makes it an ideal choice for applications that run direct from batteries without regulation.



OPA378: 0.1Hz to 10Hz noise.



OPA378: voltage noise spectral density versus frequency.

Zerø-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**

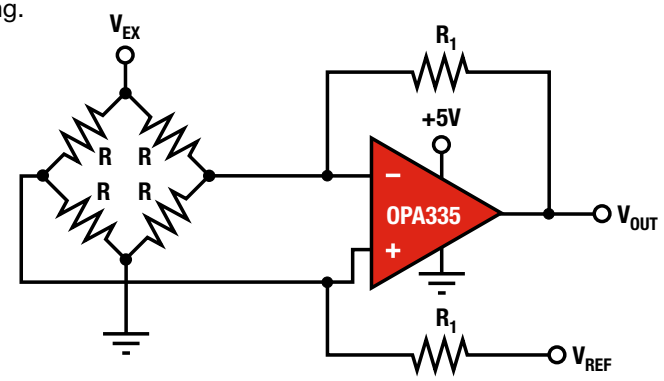
Key Features

- 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

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

Precision, Rail-to-Rail I/O Instrumentation Amplifier

INA326

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/INA326**

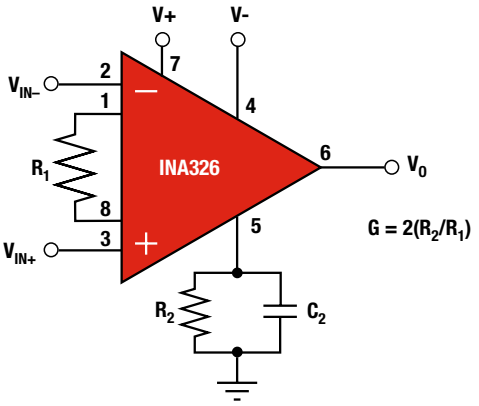
Key Features

- Low offset: 100µV (max)
- Low offset drift: 0.4µV/°C (max)
- Excellent long-term stability
- Very low 1/f noise
- Input common-mode range: 200mV below negative rail to 100mV above positive rail
- Wide output swing: Within 10mV of rails
- Single supply: +2.7V to +5.5V
- Packaging: MSOP-8, MSOP-10

The INA326 is a precision instrumentation amplifier with rail-to-rail input and output and with true single-supply operation it offers very low DC errors and input common-mode ranges that extend beyond the positive and negative rails. Excellent long-term stability and very low 1/f noise assure low offset voltage and drift throughout the life of the product.

Applications

- Medical instruments
- Multi-channel data acquisition systems
- Low-level transducer amplifier for bridges, load cells, thermocouples
- Wide dynamic range sensor measurements



INA326 functional block diagram.

4-/8-Channel, 16-Bit, Serial Output ADC for Portable Applications

ADS8331, ADS8332, ADS8341, ADS8342, ADS8343, ADS8344, ADS8345

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **ADS8331**, **ADS8332**, **ADS8341**, **ADS8342**, **ADS8343**, **ADS8344** or **ADS8345**)

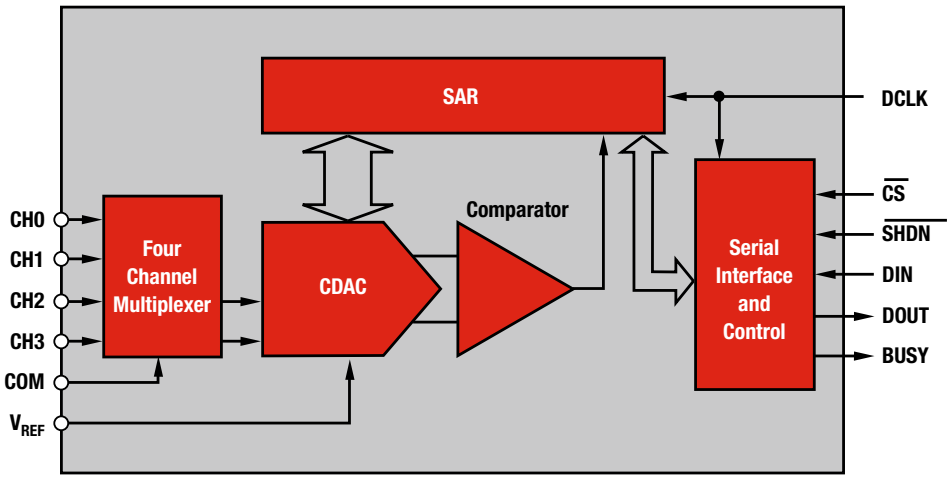
Key Features

- Conversion rate: up to 100kHz
- 4-/8-channel single-ended or 2-channel differential input
- SINAD: 86dB
- Serial interface
- Single supply: 2.7V to 5V
- Packaging: SSOP-16

Applications

- Portable medical devices
- Test and measurement
- Data acquisition

The ADS8341 is a 4-channel, 16-bit ADC with synchronous serial interface. Typical power dissipation is 8mW at a 100kHz throughput rate and a +5V supply. The reference voltage can be varied between 500mV and V_{CC}, providing a corresponding input voltage range of 0V to V_{REF}. It is tested down to 2.7V operation. The serial interface also provides low-cost isolation for remote data acquisition.



ADS8341 functional block diagram.

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

Multi-Channel, 24-Bit, Delta-Sigma ADCs

ADS1271, ADS1274, ADS1278

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **ADS1271**, **ADS1274** or **ADS1278**)

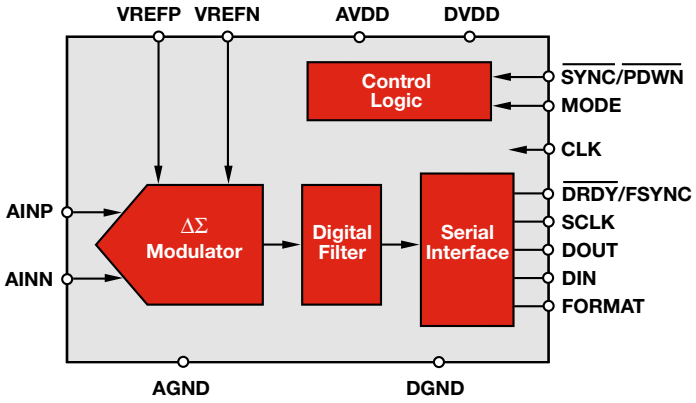
Key Features

- Single-channel or simultaneously measures 4/8 channels
- Up to 128kSPS data rate
- AC performance:
  - Bandwidth: 62kHz
  - SNR: 111dB (high-resolution mode)
  - THD: –108dB THD
- DC accuracy:
  - Offset drift: 0.8µV/°C
  - Gain drift: 1.3ppm/°C
- Linear-phase digital filter
- SPI or frame-sync serial interface
- Analog supply: 5V
- Packaging: HTQFT-64 PowerPAD™

Applications

- Pressure sensors
- Patient monitoring
- Vibration/modal analysis
- Multi-channel data acquisition
- Acoustics/dynamic strain gauges

The ADS1271, ADS1274 and ADS1278 are single-, quad- and octal-channel ADCs, respectively. These 24-bit, delta-sigma ADCs have data rates of up to 128kSPS, allowing simultaneous sampling of all channels, and are offered in identical packages for drop-in expandability. The devices offer excellent DC and AC specifications for high-precision measurement applications. They provide a usable signal bandwidth of up to 90 percent of the Nyquist rate with less than 0.005dB of ripple. Four operating modes allow for optimization of speed, resolution and power.



ADS1271/4/8 functional block diagram.

Single, Dual and Quad Fully Differential Amplifiers

THS4521, THS4522, THS4524

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/PARTnumber**
(Replace **PARTnumber** with **THS4521**, **THS4522** or **THS4524**)

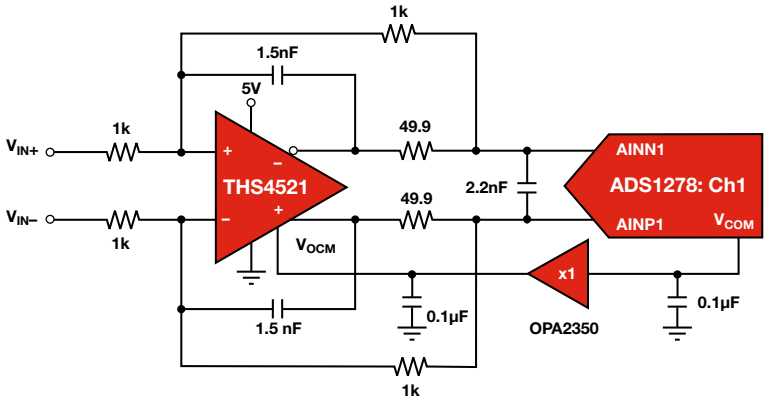
Key Features

- Low quiescent current: 1.14mA (typ)
- Power down capability: 20µA (typ)
- Input voltage noise: 4.6nV/√Hz
- Slew rate: 490V/µs
- Neg. rail-input and rail-to-rail output
- Power supply voltage: +2.5V (±1.25V) to +5.5V (±2.75V)
- Packaging1: SO-8 and MSOP-8 (THS4521), TSSOP-16 (THS4522) and TSSOP-38 (THS4524)

Applications

- Portable medical equipment
- Low power SAR and delta-sigma ADC drivers
- Low power differential driver
- Low-power differential signal conditioning

The THS4521(single), THS4522 (dual), and THS4524 (quad) are negative rail input, rail-to-rail output, fully differential amplifiers operating from a single +2.5V to +5.5V supply. The low 1.14mA/channel quiescent current and power down capability to 20µA make it a good choice for low power applications. The output common-mode control with low offset and drift allows for dc-coupling in high accuracy data acquisition systems.



THS4521 driving one channel of ADS1278 .

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

Electrocardiogram (ECG) Analog Front End Module for the C5515 ECG Medical Development Kit

TMDXMDKEK1258

Get samples, datasheets and evaluation modules at: **www.ti.com/tmdxmdkek1258**

Key Features

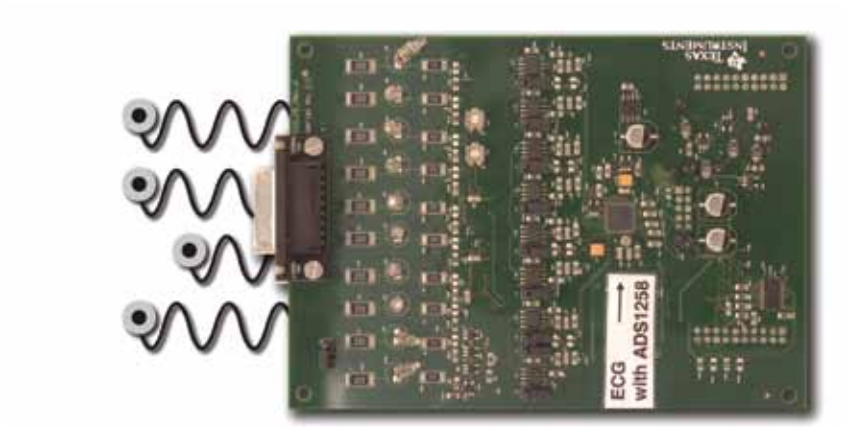
- ECG AFE module key components
  - ADS1258: 16-channel, 24-bit sigma delta analog-to-digital converter (ADC)
  - INA128: precision, low power instrumentation amplifier
  - PCA9535: remote 16-bit I^2C and SMBus low-power I/O expander
  - TLV3404: nanopower open drain output comparator
  - REF5025: low-noise, very low drift precision voltage reference
- ECG MDK system features
  - Based on industry's lowest power DSP processor – TMS320C5515
  - 12-lead ECG output using 10 electrode input
  - 0.05Hz to 150Hz bandwidth
  - Leads off detection
  - Real-time 12-lead ECG waveform display on EVM LCD, one lead at a time
  - Real-time 12-lead ECG waveform display on PC, three leads at a time
  - Heart beat rate display
  - Recording of ECG data, and offline display option of recorded ECG data

Applications

- Portable ECG devices
- Patient monitoring

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 TMDXMDKEK1258 Electrocardiogram (ECG) Analog Front End (AFE) module is part of the ECG medical development kit (MDK) that consists of the ECG AFE module, a processor board (C5515 DSP evaluation module), a set of collateral and C5515 based application sample code to implement the ECG application. The ECG MDK delivers a complete signal chain solution to enable ECG developers to build a complete ECG system quickly for evaluation and get to production faster.



TMDXMDKEK1258 EVM .

A new ECG Analog Front End module is also now available using the latest ECG ADC – the ADS1298. The P/N for this is ADS1298ECGFE-PDK and it can be used seamlessly with the C5515 EVM (TMDXEVM5515).

MDK ECG SW is freely available at:
http://code.google.com/p/c5505-ezdsp/

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 *Page 38	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
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 *Page 37	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 *Page 37	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 *Page 37	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 *Page 39	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 *Page 39	Delta-Sigma ADC	24-bit, 128kSPS, 8-channel, 111dB SNR	Simultaneous measurement, onboard decimation filter	
ADS1298 *Page 36	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 *Page 38	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 *Page 38	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
References				
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

**For additional product information see designated page number.*

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

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

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

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
MSP430F20xx	Ultra-Low-Power 16-bit MCU	1KB/2KB Flash, 128B RAM, SPI+I^{2}C 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^{2}C + 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^{2}C + 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^{2}C + 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^{2}C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	
OMAP3530	Applications Processor	ARM® Cortex-A8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at handheld power levels	OMAP3503, OMAP3515, OMAP3525
OMAP-L137 *Page 35	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
TMS320C5000™	DSP	Power efficient, high performance		
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
TMS320VC5506	DSP	200MHz, dual MAC, very low stand-by power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320VC5509A, TMS320VC5502
Power Management				
bq20z90-V110	Battery Fuel Gauge	Instant accuracy better than 1% error over lifetime of the battery	Automatically adjusts for battery aging, battery self discharge and temperature inefficiencies	bq20z70, bq20z80
bq24703	Battery Charger	0V operation, ±0.4% charge voltage accuracy, integrated PWM	Dynamic power management, multichemistry	bq24702, bq24705
bq24721C	Battery Charge Management	Multi-chemistry and multi-cell sync switch-mode charger	High efficiency, pack and system protection functions	

**For additional product information see designated page number.*

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

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

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
bq29330	Battery Safety	Battery pack full-protection analog front end	Provides individual cell voltages and battery voltage to battery management host	
DCH010505D	Galvanic Isolated, DC/DC Conv.	1W, 3kV isolation, minimal external components	Safety isolation, removal of ground loops	DCH010512/15 DCR021205
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
TPS3808Gxx	Voltage Supervisor	Low quiescent current, programmable-delay	Circuit initialization and timing supervision	TPS310x
TPS54350	DC/DC Converter	4.5 to 20V_{IN} 3A DC/DC w/integrated switch FET, sync pin, enable	Eliminate beat noise/ceramic caps/FPGA/integration	TPS54550
TPS61097-33	Boost Converter with Bypass Switch	Highly efficient, operates down to 0.3V; bypass switch; 5nA shutdown current; SOT-23	Supper efficient boost, works over entire battery range, low quiescent current, integrate the bypass switch, small package	
TPS62110	Step-Down Converter	3.1V to 17V V_{IN}, 1.5A conversion, synchronization pin, low battery indicator, power save mode	Very low noise/high efficiency	TPS62050
TPS62230	Step-Down Conv.	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62400	Dual Output Step-Down Conv.	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410
TPS63030	Buck-Boost Converter	1A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
TPS65130	Boost Converter	800mA switch, adjustable, dual output, positive/negative boost	Two supplies from one switcher	
TPS717xx	Single-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS795xx, TPS799xx
TPS718xx-yy	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719xx-yy
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low I_Q 500nA	DVS voltage designed to operate with MSP430 to increase power savings	TPS78101
TPS79901	Single Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS79501, TPS74301
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2 to 500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication	CC2510, CC2511
CC2530/CC2531	Second Gen. System-on-Chip 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
CC2540	2.4GHz *Bluetooth*® Low Energy Compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	Fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	
Toolkits				
TMDXMDKEK1258 **Page 40*	ECG Analog Front End Module for the C5515 ECG Medical Dev. Kit	12-lead ECG output using 10 electrode input; 0.05Hz to 150Hz bandwidth; leads off detection; heart beat rate display	Based on industry's lowest power DSP processor – TMS320C5515	

**For additional product information see designated page number.*

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

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

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.

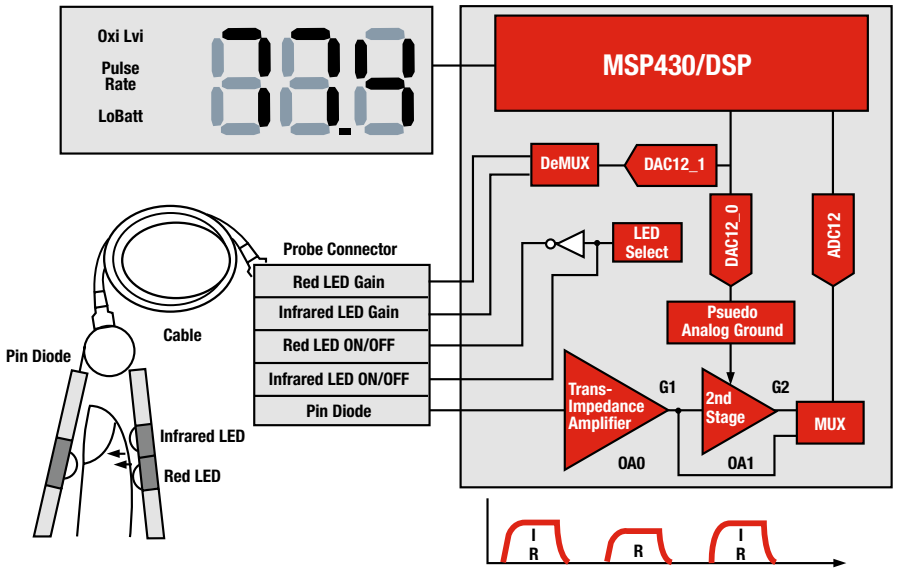
Light sources, typically light-emitting diodes (LEDs), shine visible red and infrared light. Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red light. Highly oxygenated hemoglobin allows more red light to pass through and absorbs more infrared light.

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.



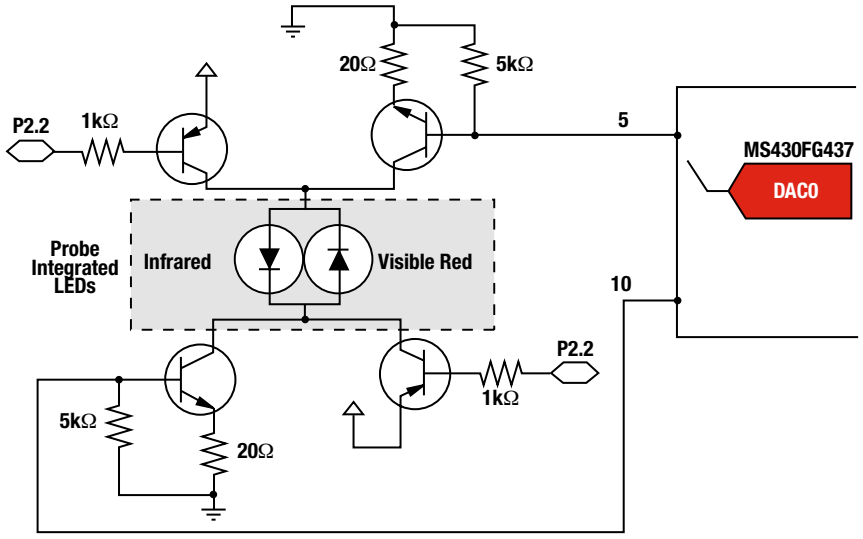
Apart from the MCU and four transistors, only passive components are needed for this design.

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.

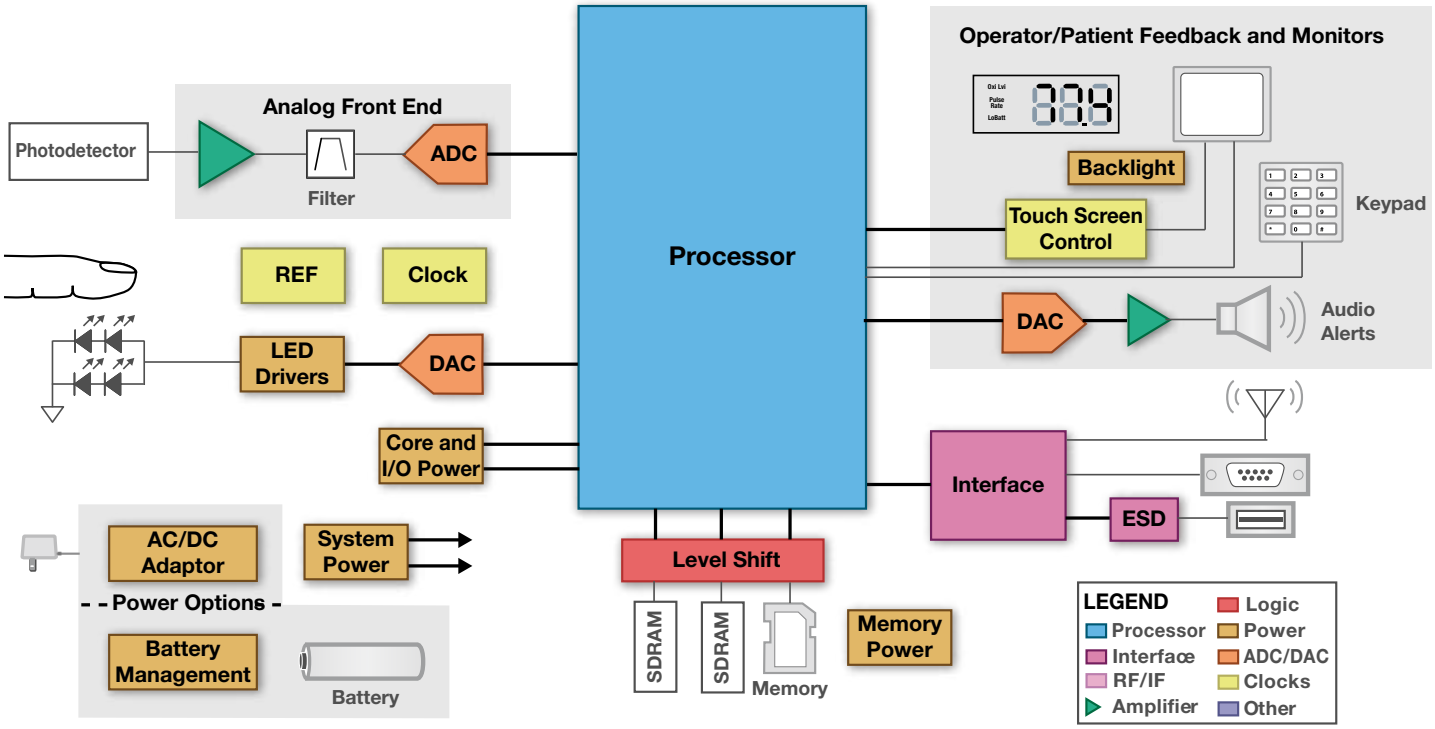
Pulse Oximeter

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.



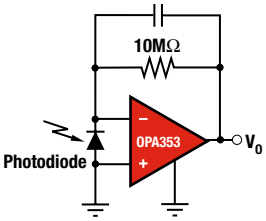
Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

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.

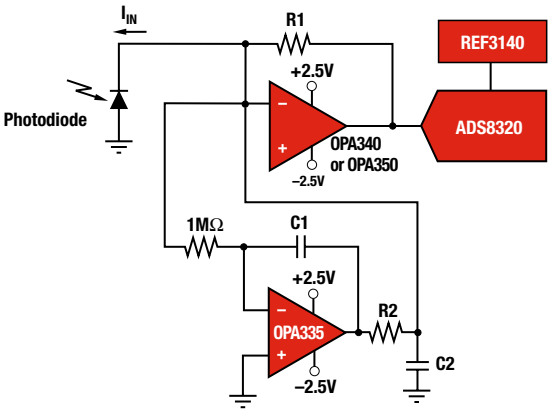
Using one photodiode with two IVC102s eliminates dark current and ambient light errors, since errors common to both can be subtracted.

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.

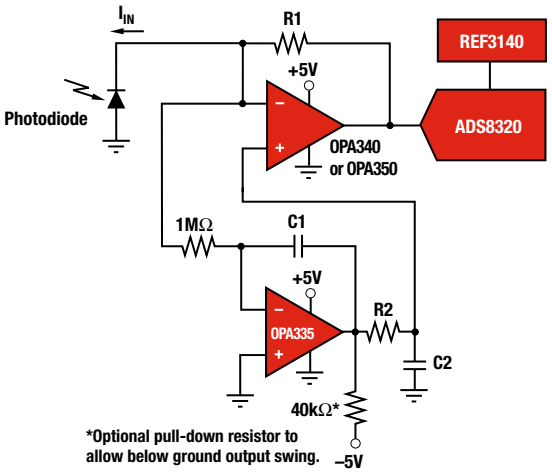
Transimpedance Amplifier Requirements

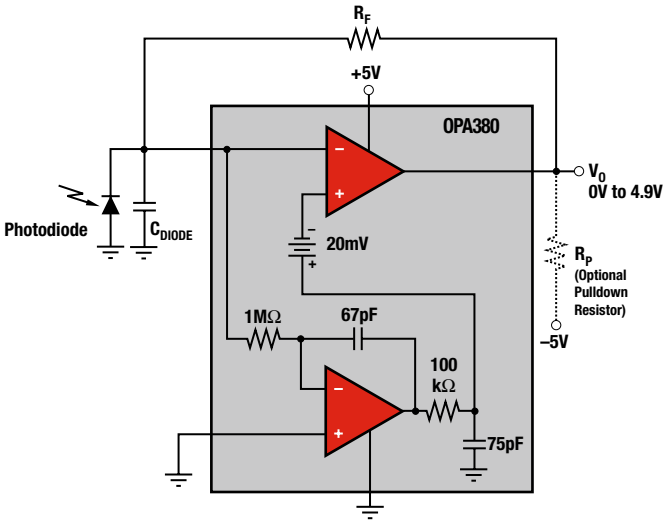
- Low input bias current over temperature range of interest
- Low input capacitance relative to photodiode capacitance
- High gain-bandwidth product
- Low voltage noise
- For maximum precision, low offset drift over temperature
- For single-supply systems:
  - Rail-to-rail input (including OV) and output 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.

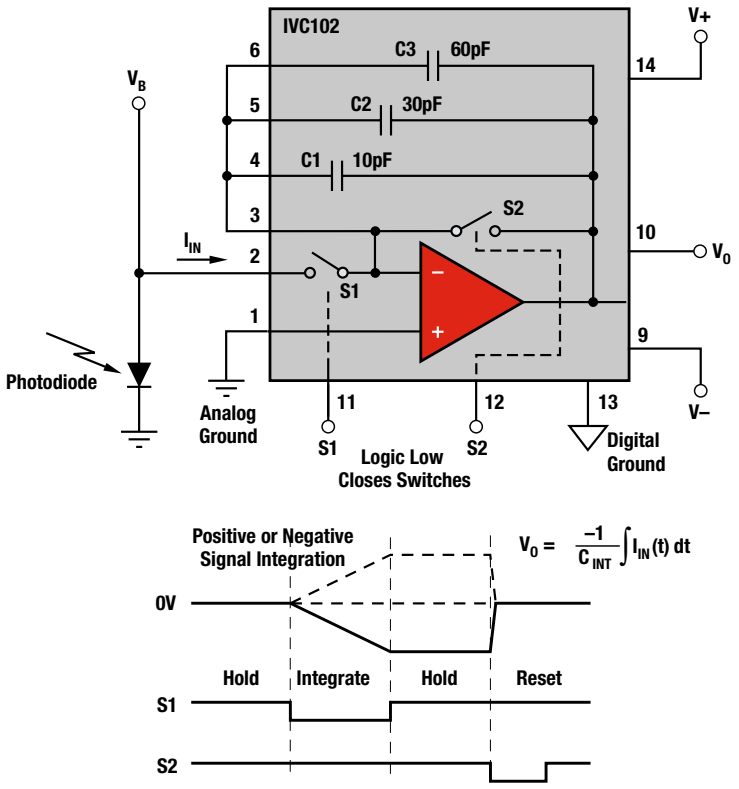
If the photodiode shunt resistance is much larger than that of the feedback resistor, offset voltage is not significant. If offset voltage stability is paramount, an auto-zero solution including the OPA335 is best.

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

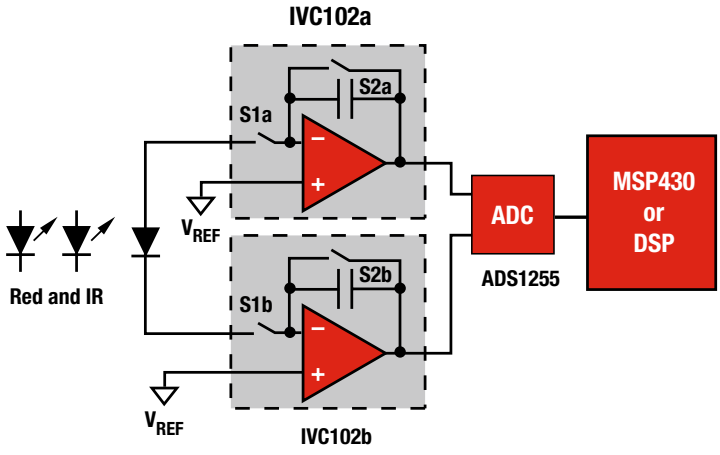
- Single-chip solution
- High resolution
- Low noise
- Wide input range by adjustable integration time
- No need for DC corrections of the diode current

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

Dual, Current-Input, 20-Bit Charge Digitizing ADC
DDC112

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/DDC112**

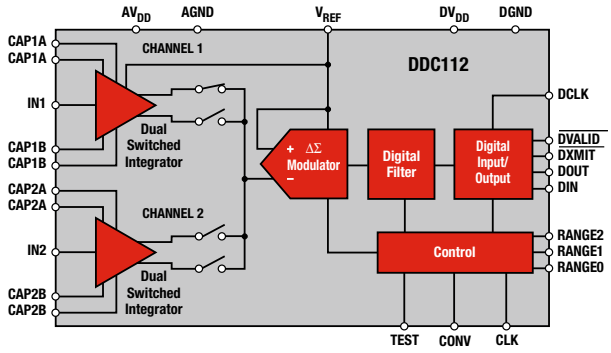
Key Features

- Single-chip solution for measuring photodiodes
- High precision, true integrating function
- Low noise: 3.2ppm, rms
- Outstanding linearity: ±0.005% INL reading ±0.5ppm FSR
- Programmable full-scale: 50 to 1000pC
- Single supply: +5V supply
- Packaging: SO-28, TQFP-32

Applications

- Blood analysis
- Liquid/gas chromatography
- Direct photosensor digitization
- Infrared pyrometry

The DDC112 is a dual input, wide dynamic range, charge-digitizing ADC which allows low-level current output ICs to be connected directly to its inputs. Charge integration is continuous as each input uses two integrators; while one is being digitized, the other is integrating. In addition to the internal programmable full-scale ranges, external integrating capacitors allow an additional user-settable, full-scale range of up to 1000pC. A high-speed serial shift register, which holds the result of the last conversion, can be configured to allow multiple, cascaded DDC112s, minimizing interconnections.



DDC112 functional block diagram.

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**

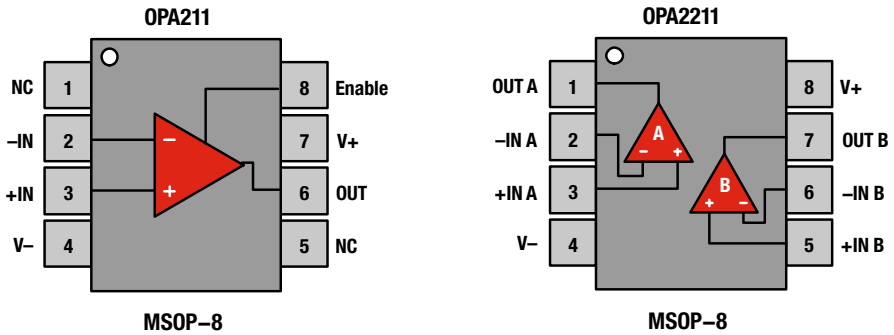
Key Features

- 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.

Pulse Oximeter

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

TMDXMDKPO8328

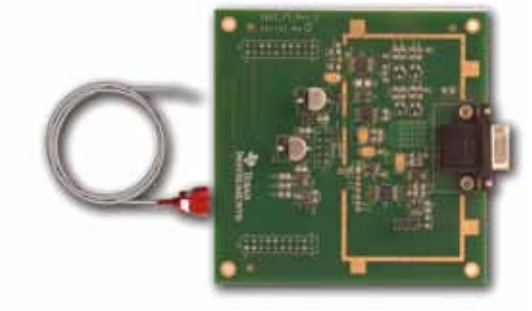
Get samples, datasheets and evaluation modules at: **www.ti.com/tmdxmdkpo8328**

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

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	
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 **Page 48*	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
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
OPA350	Op Amp	500µV V_{OS}, 38MHz, 2.5V to 5V supply		
OPA353	MicroAmplifier™ Series	High speed, single supply, rail-to-rail		
OPA363	Op Amp	1.8V, high CMR, RRIO, shutdown		OPA364
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
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	
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	

**For additional product information see designated page number.*

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

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

Pulse Oximeter

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
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	
DDC112 *Page 48	Dual Current Input ADC	Wide dynamic range, charge digitizing, 20-bit ADC	Single-chip solution	
References				
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
Processors				
MSP430F20xx	Ultra-Low-Power 16-Bit MCU	1KB/2KB Flash, 128B RAM, SPI+I^{2}C	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^{2}C + 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^{2}C + 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^{2}C + 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^{2}C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, comparator_A, 2 op amps	
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

**For additional product information see designated page number.*

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

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

Pulse Oximeter

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
TMS320C5000™	DSP	Power efficient, high performance	Fixed-point DSP with industry's best combination of standby and dynamic power consumption	
TMS320C5505	Low-Power DSP	16-/8-bit EMIF, 320K bytes on-chip RAM, USB 2.0 full- and high-speed device	High-performance, low-power	
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
TMS320VC5506	DSP	200MHz, dual MAC, very low stand-by power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320VC5509A, TMS320VC5502
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
Power Management				
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
bq27500	Fuel Gauge	System side Impedance Track™	Accurately know remaining battery capacity, state-of-charge, run-time to empty	
TPS61081	LED Boost Converter	Input to output isolation	Protection from short between any pins and between any pin to ground	TPS61042
TPS61093	OLED Boost Converter	Wide V_{IN} range, input-output disconnect	Flexible, fail safe solution	TPS61080
TPS62230	Step-Down Converter	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410
TPS63030	Buck-Boost Converter	1A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
TPS717xx	Single-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS795xx, TPS799xx
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
TPS718xx-yy	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719xx-yy
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low I_Q 500nA	DVS voltage designed to operate with MSP430™ to increase power savings	TPS78101
TPS78001	Single-Channel LDO	Dual-level, fixed output voltages, ultra-low I_Q	Adjustable V_{OUT} for optimal performance, longer battery life	TPS78101
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2 to 500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 Chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511

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

Pulse Oximeter

Component	Description	Key Features	Benefits	Other TI Solutions
RF ICs (Continued)				
RF Systems-on-Chip (Continued)				
CC2530/31	Second Generation 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 SOC for quick time to market; provides a robust and complte ZigBee USB dongle or firmware-upgradable network node.	CC2590/91, CC2530ZNP
CC2530ZNP	Second Generation Zstack Network Processor	ZigBee stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated, excellent selectivity and blocking performance systems; excellent coexistence with *Bluetooth* ® technology and Wi-Fi.	
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	
Toolkits				
TMDXMDKP08328 **Page 49*	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	

**For additional product information see designated page number.*

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

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

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.

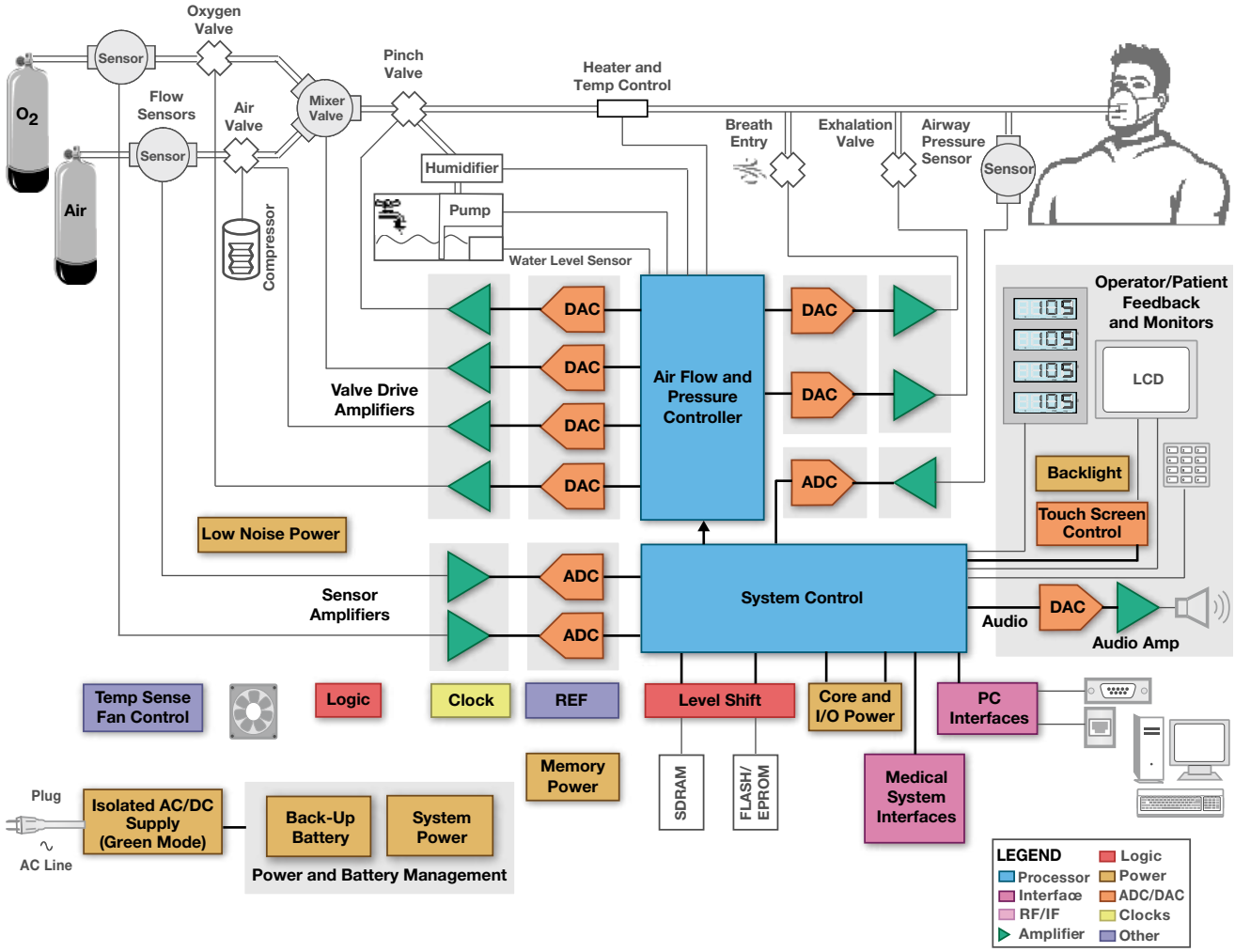
TMS320C2000™ 32-bit controllers are used in portable respiration applications like portable oxygen concentrators because the real-time control capability allows for very precise control of the BLDC motor, even at high speeds. This optimizes system power consumption and enhances the durability and reliability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

Further Information

Pressure sensors play an important role for respiration equipment. See page 53 for a short tutorial on pressure sensing techniques and considerations.

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
- Stellaris® Cortex M3 microcontrollers



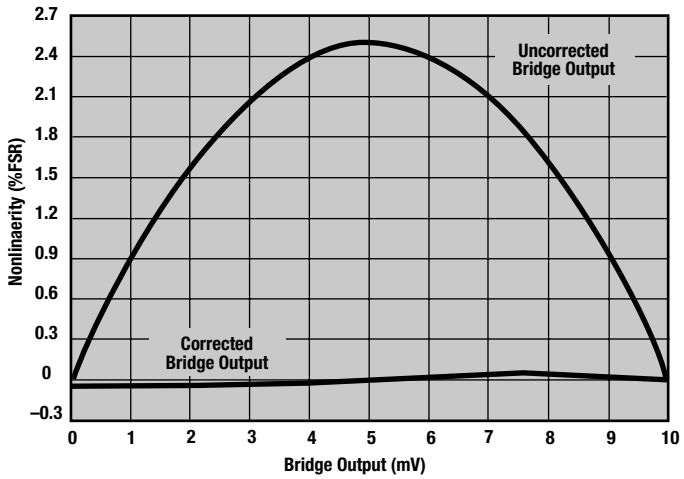
Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

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.

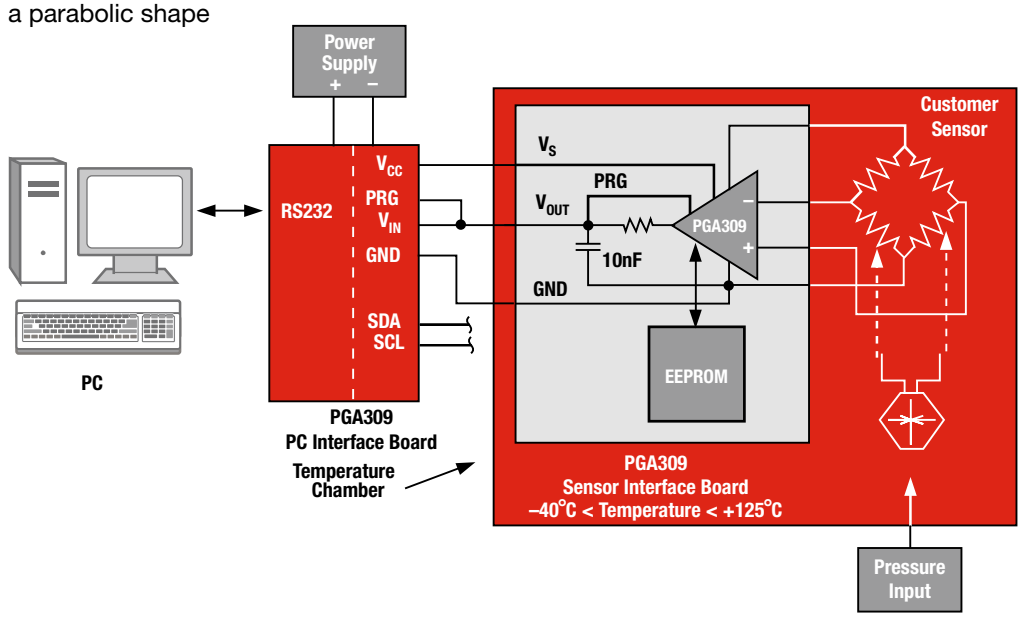
Sensor Signal Conditioning — performs all necessary functions to calibrate, compensate for temperature variance, scale, and linearize the sensor signal.

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™

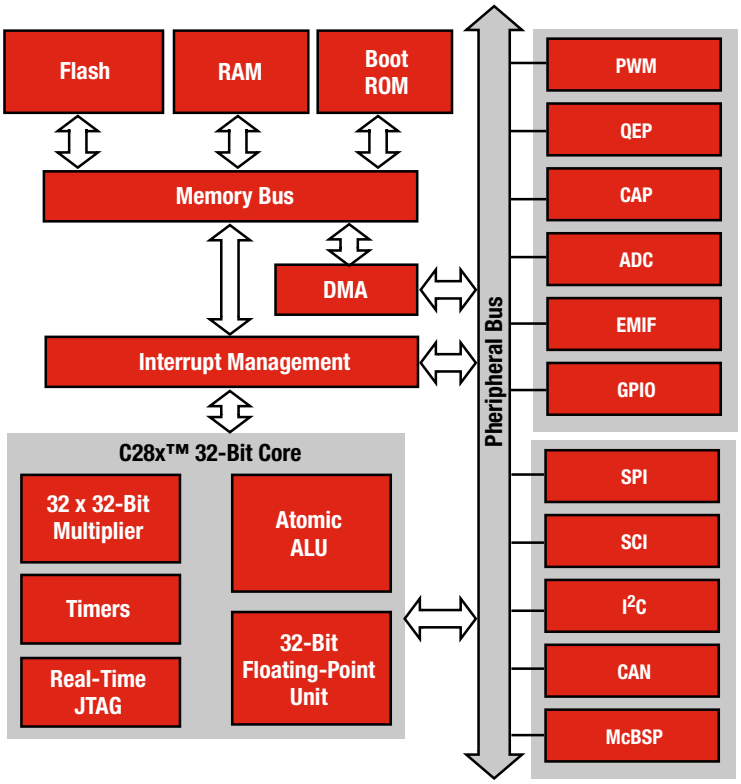
Get samples and datasheets at: **www.ti.com/c2000**

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

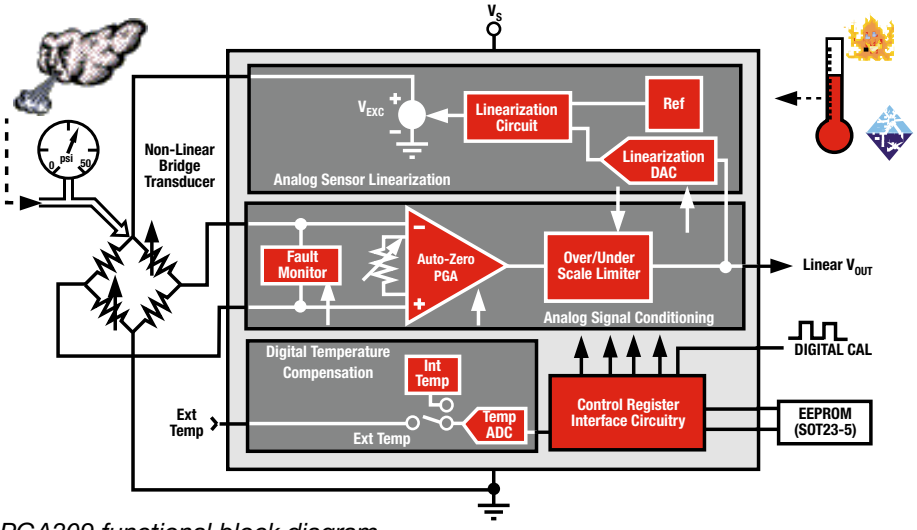
- Ratiometric or absolute voltage output
- Digitally calibrated via single-wire or two-wire interface
- Eliminates potentiometer and trimming
- Low, time-stable total adjusted error
- +2.7V to +5.5V operation
- Packaging: Small TSSOP-16

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**

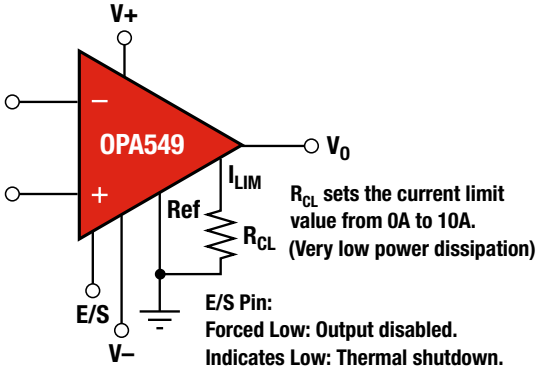
Key Features

- 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**)

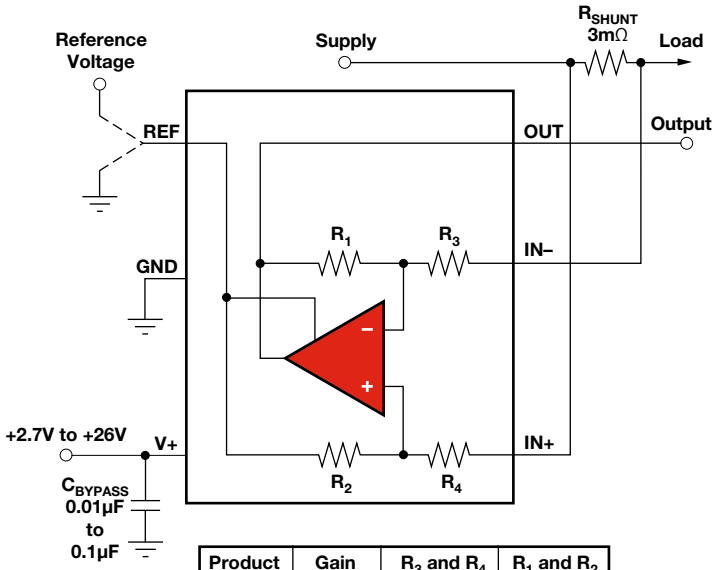
Key Features

- 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				
DRV8402	PWM Motor Driver	24A peak current, 52.5V supplies, 500kHz PWM input	Precision motor control in a complete integrated solution	
INA210/11/12/13/14 *Page 57*	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	
OPA549 *Page 56*	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 *Page 56*	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, 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	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+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	
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 + I^2C + 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 + I^2C + UART/LIN + IrDA, 128 LCD controller	5 ch. 16-bit SD ADC, 2 ch. 12-bit DAC, A-comp, 2 op amps	
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
Stellaris® LM3S3xxx	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	

**For additional product information see designated page number.*
To view more system block diagram compatible products, visit ***www.ti.com/medical***

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

Ventilator

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors (Continued)				
TMS320C28x™ *Page 55	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	
TMS320VC5506	DSP	200MHz, dual MAC, very low standby power of 0.12mW	Supported by eXpressDSP™ and many other software packages and tools	TMS320VC5509A, TMS320VC5502
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	
Power Management				
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
bq27010	Battery Fuel Gauge	Li-Ion and Li-Pol battery gas gauge	Reports accurate time-to-empty of battery	bq27200
bq27540	Battery Fuel Gauge	Li-Ion battery gas gauge with Impedance Track™ fuel-gauge technology	Reports accurate time-to-empty of battery	bq27510
TPS2041B	USB Power Switches	USB compliant power source, short-circuit protection	Single-chip power-source solution for USB and memory cards	TPS2550, TPS2061
TPS22902	Load Switch w/ 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 1.8 V	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	
TPS61042	LED Boost Converter	Current source with over voltage protection	Simple backlight boost for improved visibility of LCD	TPS61140
TPS61097-33	Boost Converter with Bypass Switch	Highly efficient, operates down to 0.3 V; bypass switch; 5nA shutdown current; SOT-23	Super efficient boost, works over entire battery range, low quiescent current, integrate the bypass switch, small package	
TPS61240	Boost Converter	Input current limit, load disconnect during shutdown	Small, fail save solution	TPS61070
TPS62230	Step-Down Converter	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410
TPS62750	Step-Down Converter	Programmable input current limit, hot plug and reverse current protection	Supports USB powerde applications and large output caps	TPS62040

**For additional product information see designated page number.*

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

Ventilator

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
TPS63000	Buck Boost Converter	Automatic transition between step down and boost mode	Produce mid-range voltage out over entire range of battery	TPS62113
TPS63030	Buck-Boost Converter	1-A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
TPS717xx	Low-Noise Single-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS793xx, TPS795xx, TPS799xx
TPS718	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low I_Q 500nA	DVS voltage designed to operate with MSP430™ to increase power savings	TPS78101
TPS79901	Low-Noise Single-Channel LDO	Very high rejection of power source noise	Low-noise power rails for sensitive analog components	TPS793xx, TPS795xx
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC2510/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	Second Generation 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 SOC for quick time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP
CC2540	2.4 GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	Fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations ; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	

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

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

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.

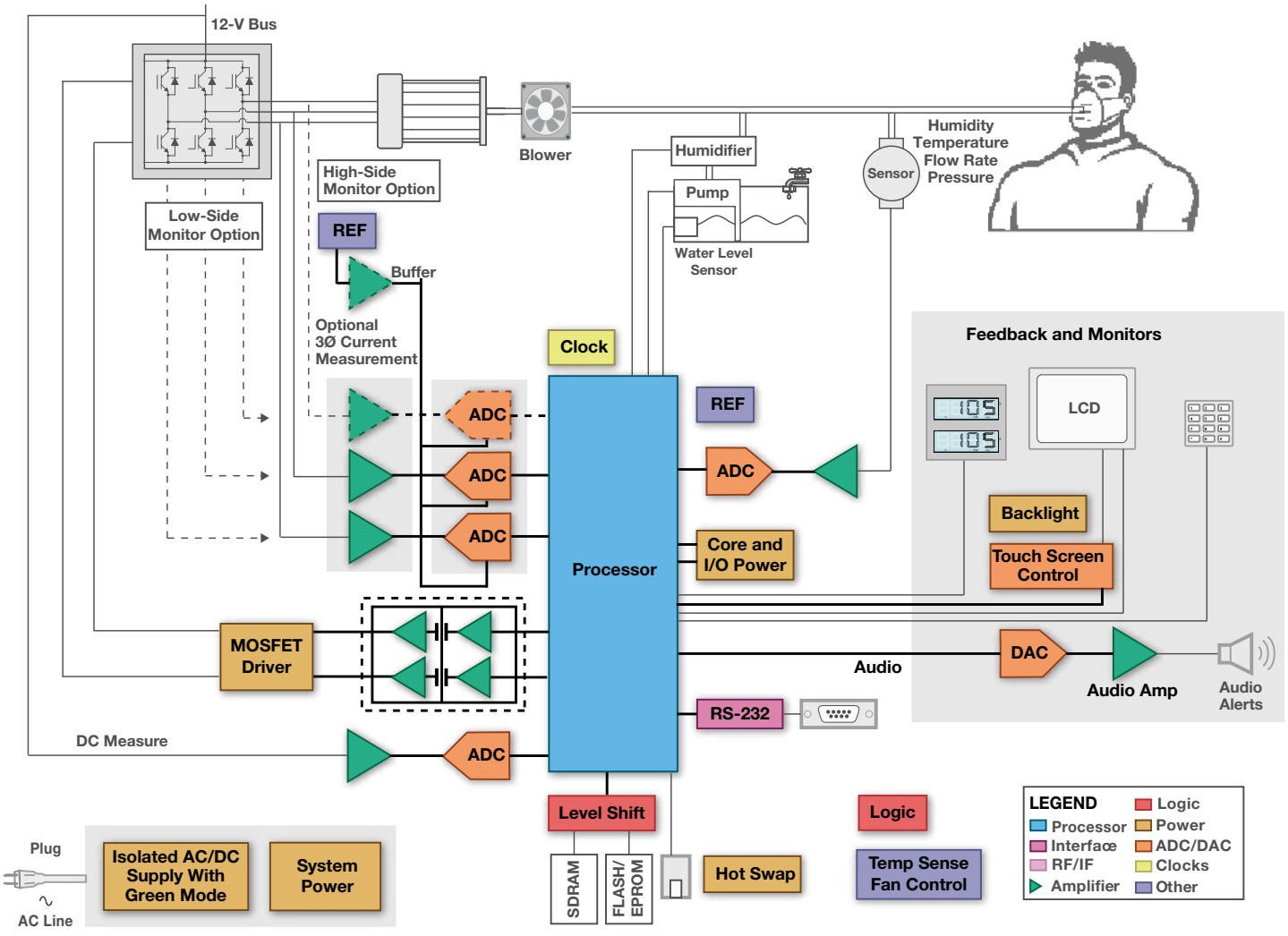
The sensors are very cost-effective. Large offset and offset drift cause the signals to be off-scale, temperature-variant and nonlinear. Amplifiers with low offset voltage and drift over time and temperature are ideal for signal conditioning.

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**

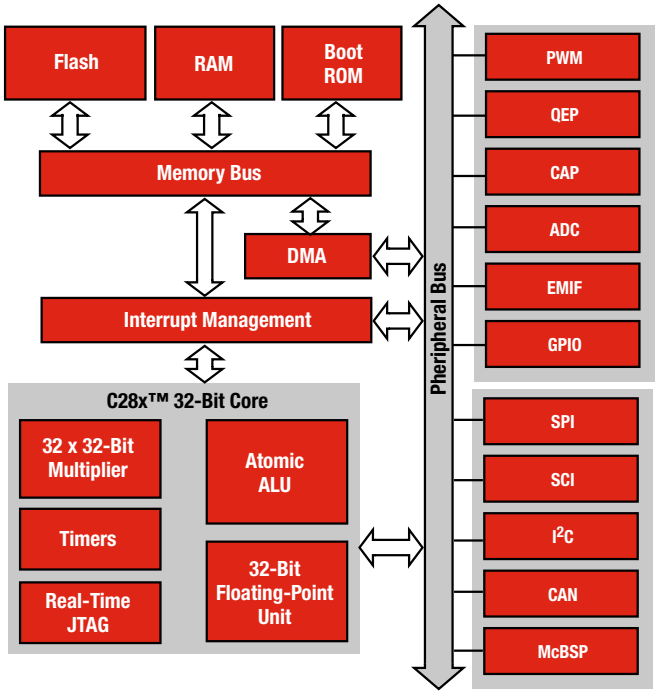
Continuous Positive Airway Pressure (CPAP) machines are an effective means of preventing intubation, decreasing mortality in patients with acute respiratory failure, helping patients with sleep apnea and reducing chronic respiratory failure.

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:

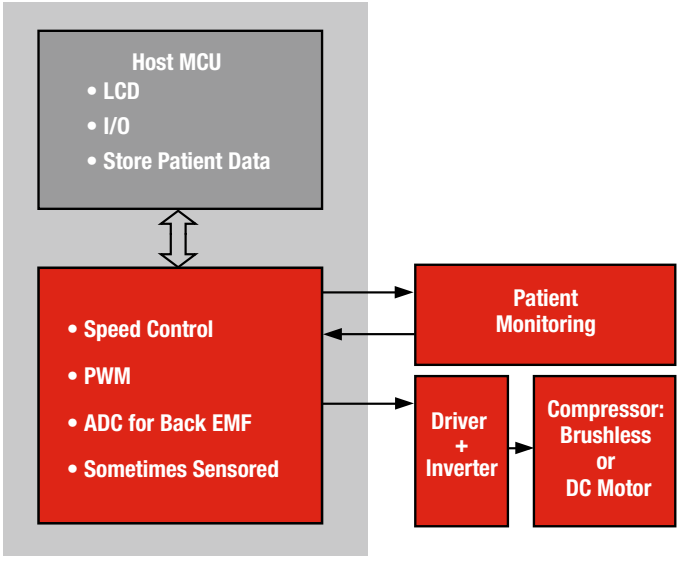
1. TMS320C2000 32-bit microcontrollers are high-performance, low-cost ICs that control motor speed, position and torque in real time. If necessary these controllers can even provide the processing power for executing highly sophisticated position and speed estimation algorithms to control the motor using 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
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
TMS320C2000™ *Page 62	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
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
Stellaris® LM3S3xxx	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	
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

**For additional product information see designated page number.*

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

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Continuous Positive Airway Pressure (CPAP)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters (Continued)				
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				
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
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	
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	
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	
Amplifiers				
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

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

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

Continuous Positive Airway Pressure (CPAP)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers (Continued)				
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	
Power Management				
TPS2550	USB Power Switch	Adjustable current-limited power-distribution switch	Allows custom current set limit for different designs	
TPS2811	MOSFET Driver	Inverting dual high-speed MOSFET drivers with internal regulator	Saves solution space	
TPS3103E12	Supervisory Circuit	Ultra-low-supply-current/supply-voltage supervisory circuit	Saves battery power	
TPS3813I50	Supervisory Circuit	Supervisor with programmable watchdog window	Allows custom time intervals	
TPS40077	DC/DC Controller	Wide-input (8V to 40V), up to 1MHz-frequency synchronous buck controller, source only	Higher frequency requires smaller inductor and input capacitor	
TPS40200	DC/DC Controller	4.5V to 52V input non-synchronous buck DC/DC controller	Very wide input allows wider range of solutions	
TPS5410	DC/DC Converter	5.5V to 36V input, 1A step-down converter	Wide input range provides for mulitple input solutions	
TPS54310	DC/DC Converter	Low-input-voltage, 3A synchronous buck converter with adjustable output voltage	Higher efficiency with synchronous solution	
TPS54350	DC/DC Converter	4.5 to 20V_{IN}, 3A DC/DC with integrated switch FET, sync pin, enable	Eliminate beat noise/ceramic caps/FPGA/integration	TPS54550
TPS61050	White LED Driver	1.2A high-power white LED driver with I^2C-compatible interface	Provides I^2C control	TPS61058
TPS61093	OLED Boost Converter	Wide V_{IN} range, input-output disconnect	Flexible, fail safe solution	TPS61080
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	
TPS61160	White LED Driver	White LED driver with digital and PWM brightness control in 2mm x 2mm package	Will allow stepped brightness adjustment	TPS61061
TPS62110	Step-Down Converter	3.1V to 17V V_{IN}, 1.5-A conversion, synchronization pin, low battery indicator, power save mode	Very low noise/high efficiency	TPS62050
TPS62230	Step-Down Converter	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm2 solution size	TPS62260
TPS62750	Step-Down Converter	Programmable input current limit, hot plug and reverse current protection	Supports USB powerde applications and large output caps	TPS62040
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	

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

Continuous Positive Airway Pressure (CPAP)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
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	DC/DC Converter	800mA boost current w/positive and negative (dual) output for OLED and CCD sensor	Provides smaller solution size	
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	
TPS75103	LDO	Low-dropout, two-bank LED driver with PWM brightness control	Will allow stepped brightness adjustment	
TPS75105	LDO	Low-dropout, two-bank LED driver with PWM brightness control	Will allow stepped brightness adjustment	
TPS767D301	LDO	Dual-output LDO voltage regulator	Core and I/O voltage rails in one LDO	
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	

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

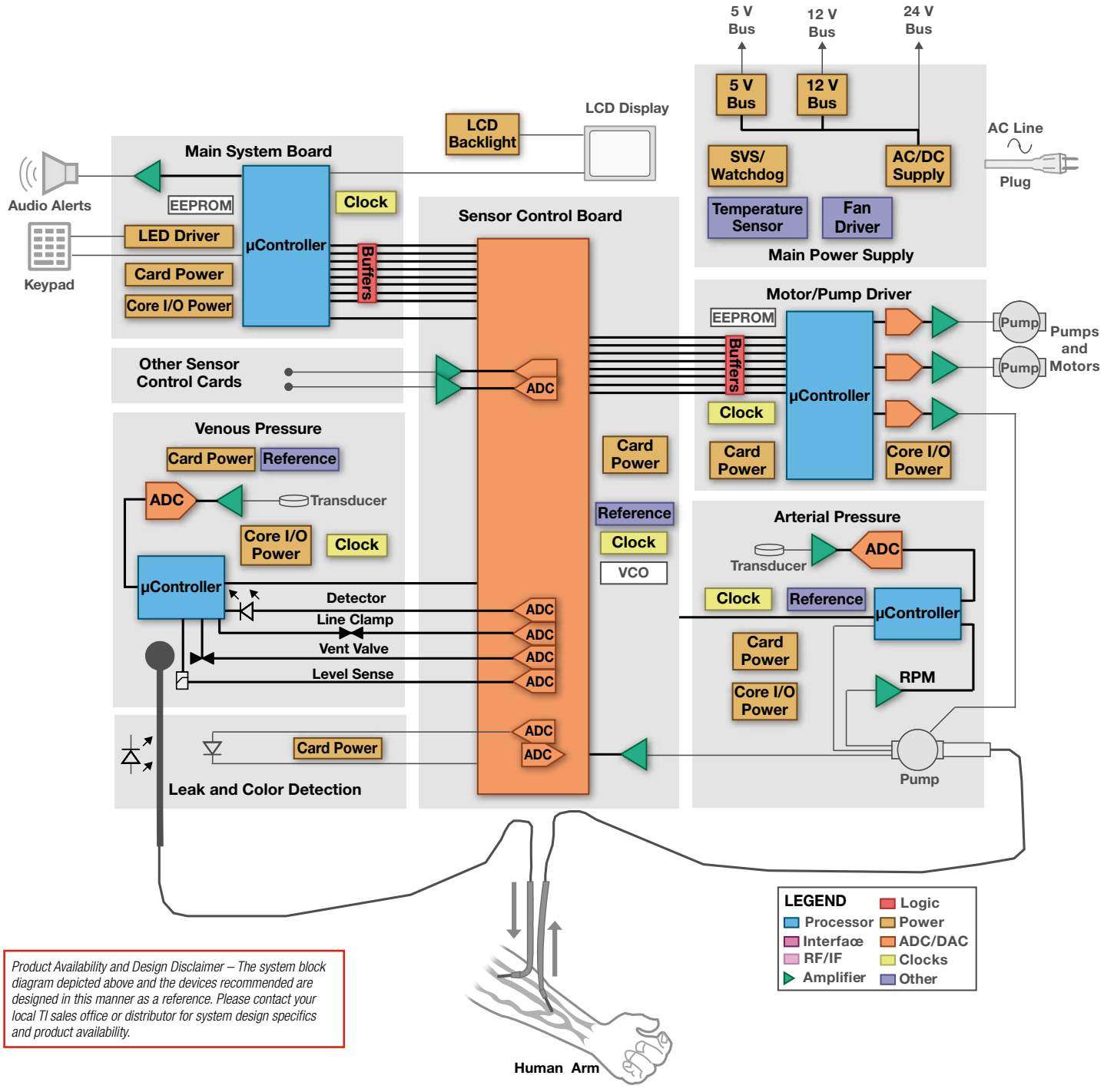
Dialysis Machine

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
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, 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
Stellaris® LM3S3xxx	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	
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
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 .04 mm 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

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

Dialysis Machine

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters (Continued)				
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
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
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	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
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	
Power Management				
TPS40054	DC/DC Controller	Wide V_{IN} buck controller with selectable switching frequency	Allows designer to select best combination of input voltage and switching frequency	
TPS40077	DC/DC Controller	Buck controller with 5-/12-/24-input voltage ranges	Covers most common intermediate voltage buses	
TPS54310	DC/DC Controller	3A switcher with intregrated FETS	Provides controller and FETS in one package for best solution size	
TPS54350	DC/DC Converter	4.5 to 20V_{IN} 3A DC/DC with integrated switch FET, sync pin, enable	Eliminate beat noise/ceramic caps/FPGA/integration	TPS54550
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
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	
TPS75003	Linear Charge Management	Integrated triple-supply power management IC for Xilinx® Spartan®	Provides all three rails in one package	
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

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

Infusion Pump

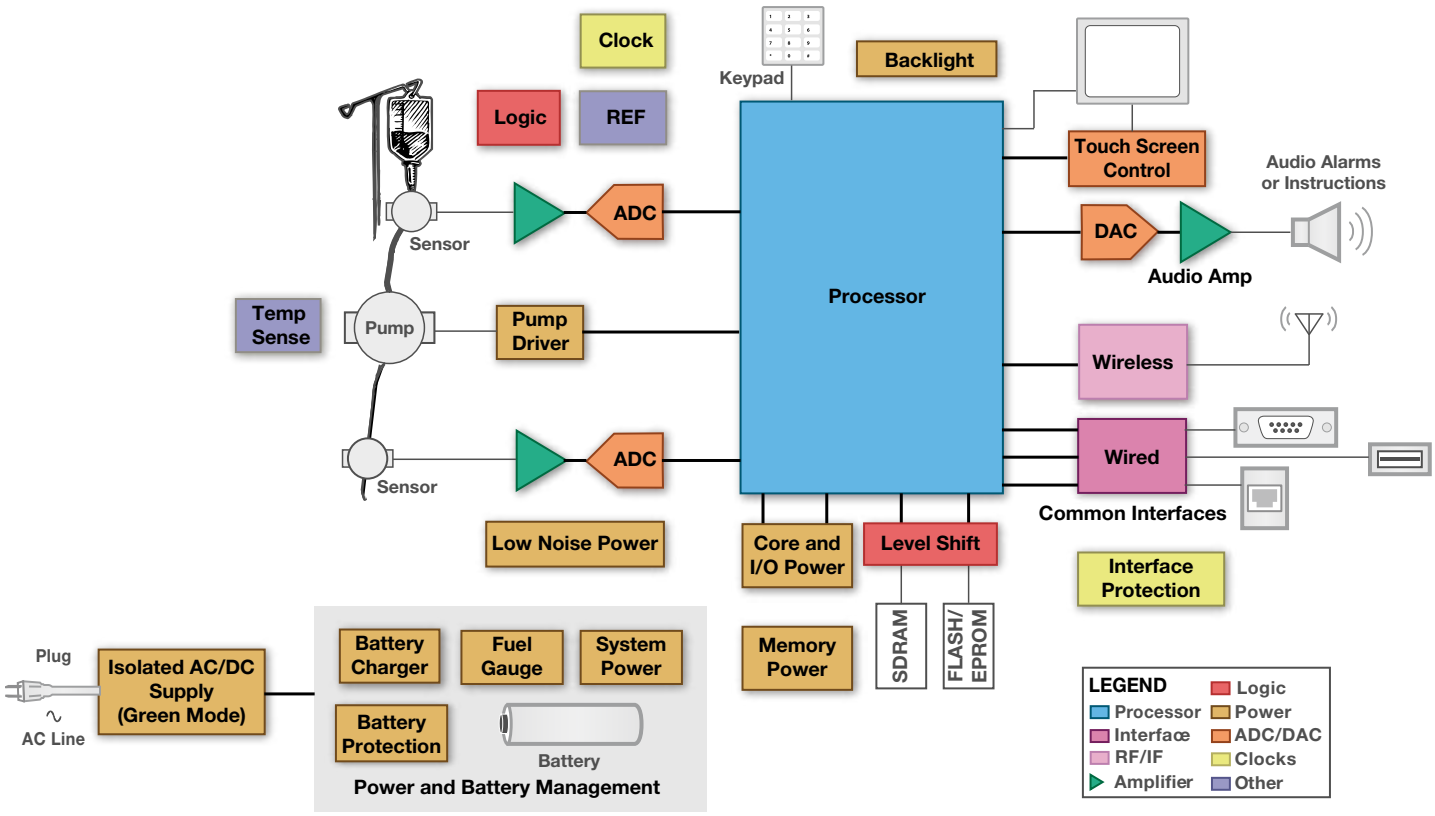
Infusion pumps are an effective pathway to deliver fluid, blood, and medication to a patient's vital organs. Since the entire blood supply within a human body circulates within 60 seconds, substances introduced into the circulatory system are distributed rapidly.

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
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	32 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	92 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
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
Stellaris® LM3S3xxx	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	
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
Data Converters				
ADS1246	Delta-Sigma ADC	24-bit, 2kHz with PGA, 50/60Hz noise rejection	Integration with performance and low power	ADS1247, ADS1248,
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		
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		

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

Infusion Pump

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers (Continued)				
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
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency hopping systems	CC2500
CC1150	Sub-1GHz Transmitter	Programmable data rate from 1.2 to 500 kBaud; fast startup time (0.3µs); low current consumption	Fast development time and low system cost; flexible optimization of range vs. power; small solution size	
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	CC2520
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2431	System-on-Chip Solution for ZigBee location engine	CC2431 has 32/64/128 KB hardware AES encryption engine, excellent selectivity, blocking performance and hardware location	Ideal for battery operated systems; suitable for proprietary and ZigBee systems; adds location awareness and accuracy of 3 to 5 meters	
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 SOC for quick time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity and blocking performance systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	
Power Management				
bq2000	Battery Management	Multi-chemistry charger	One charge for both Li-Ion and NiCad/NiMH cells	
bq2016	Battery Management	High-discharge-rate battery monitor	Provides true discharge rate for high-current battery pack	
bq20z80A-V110	Battery Management	Patented Impedance Track™ ICs	Accurately measures available cell charge	

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

Infusion Pump

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
TPS40054/5	DC/DC Controller	Wide V_{IN} controller with adjustable switching frequency	Allows flexibility for the input and the switching frequency	TPS40057
TPS40057	DC/DC Controller	Wide V_{IN} controller with adjustable switching frequency	Allows flexibility for the input and the switching frequency	TPS40054/5
TPS40077	DC/DC Controller	4.5 to 28V input	Supports 5-/12-/24-V intermediate bus voltages	
TPS51020	DC/DC Controller	Synchrounous dual buck controller	Provides two outputs 180° apart in one package	TPS5124
TPS51116	DC/DC Controller	Complete DDR/DDR2 solution	Provides all output and active termination for DDR	
TPS5124	DC/DC Controller	Synchrounous dual buck controller	Provides two outputs 180° apart in one package	TPS51020
TPS54110	DC/DC Converter	Externally compensated — adjustable 1.5A integrated FET switcher	Provides flexibility and ease of design	
TPS54310	DC/DC Converter	Externally compensated — adjustable 3A integrated FET switcher	Provides flexibility and ease of design	
TPS54350	DC/DC Converter	4.5 to 20V input, 3A DC/DC with integrated switch FET, sync pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS62040	DC/DC Converter	Adjustable 1.2A, 95%-efficient step-down converter, 18µA, MSOP-10	Maximizes battery life with high efficiency and low I_Q	
TPS62220	DC/DC Converter	300mA step-down converter in a SOT-23 package	Small solution size with high-side FET	
TPS62300/1/2/3/5	Step-Down Converter	500mA, 3MHz synchronous step-down converter	Very small inductor and high efficiency	TPS62040
TPS62350	DC/DC Converter	Step-down DC/DC converter with I^2C interface for dynamic voltage scaling	Provides ability to increase conversion efficiency	
TPS65010	Linear Charge Management	Fully intregrated power and battery management IC	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	
TPS71701	LDO	Low-noise, high-bandwidth-PSRR, low-dropout 150mA linear regulator	Filters out wider range of incoming noise with the high PSRR	TPS718xx family
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	
TPS76725	LDO	1A single-output LDO with low I_Q 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	
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	

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

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).

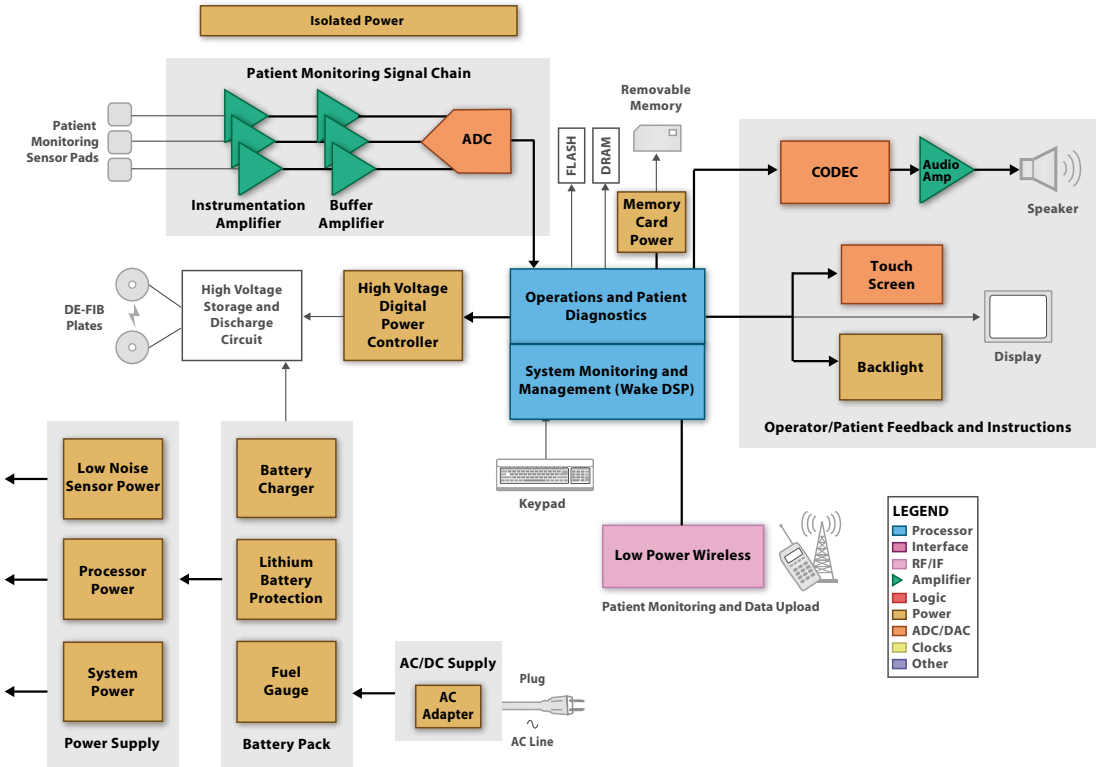
Then, following the instructions, the operator presses the shock button to deliver the high-voltage pulse; so current begins flowing through the body to depolarize most of the heart cells, which often re-establishes coordinated contractions and normal rhythm. The amount of flowing current is determined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

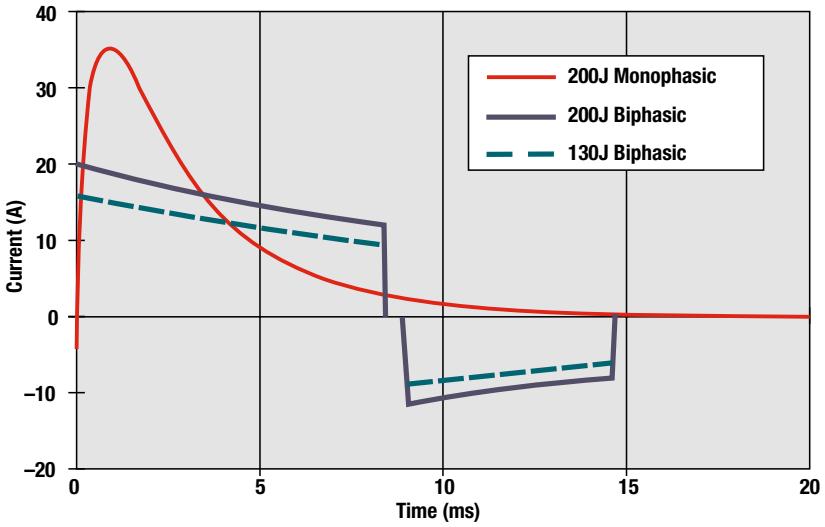


Product Availability and Design Disclaimer – The system block diagram depicted above and the devices recommended are designed in this manner as a reference. Please contact your local TI sales office or distributor for system design specifics and product availability.

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**

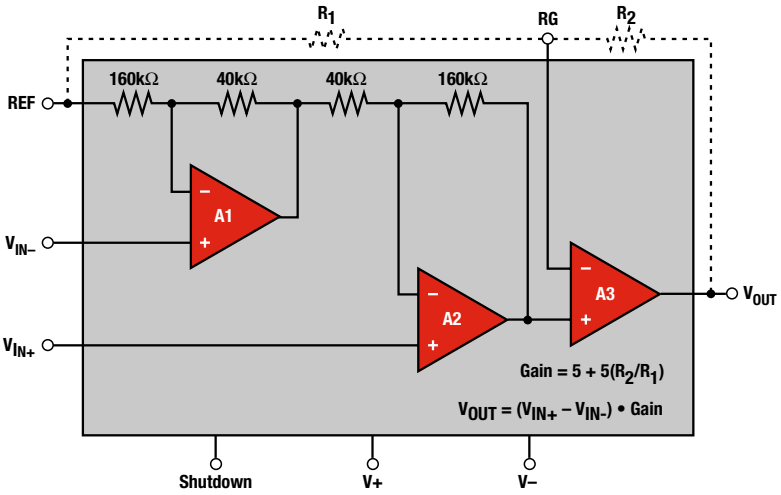
Key Features

- 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 *Page 75	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
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)
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 .04 mm 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	
References				
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
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

**For additional product information see designated page number.*

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

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

Automated External Defibrillator (AED)

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
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	
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
Stellaris® LM3S3xxx	Microcontroller	ARM® Cortex-M3, up to 256KB flash, up to 64kB RAM, USB host/device	USB, 10-bit ADC, temperature sensor	
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	TMS320VC5509A, TMS320VC5502
Power Management				
bq20z90-V110	Battery Fuel Gauge	Instant accuracy better than 1% error over lifetime of the battery	Automatically adjusts for battery aging, battery self discharge and temperature inefficiencies	bq77PL900
bq24100	Battery Charge Management	Switch mode, 1100kHz switching frequency, >2A charge current	d/dt, min current primary charge termination method	
bq24721C	Battery Charge Management	Multi-chemistry and multi-cell sync switch-mode charger	High efficiency, pack and system protection functions	
bq29330	Battery Safety	Battery pack full-protection analog front end	Provides individual cell voltages and battery voltage to battery management host	
DCP020515D	Isolated DC/DC Converter	2W, unregulated, up to 89% efficiency, 106W/in3 power density	EN55022 Class B EMC performance, UL1950 component	DCP02 series
TPS2041B	USB Power Switch	USB-compliant power source, short-circuit protection	Single-chip power source solution for USB and memory cards	TPS2550, TPS2061

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

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

Automated External Defibrillator (AED)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
TPS22902	Load Switch with Controller Turn-On	Low on resistance, controlled turn-on, ultra small 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
TPS2550	USB Power Switch	Precision OC USB power switch with UL approval	Provides precise adjustable current limit for multiple applications	TPS2551
TPS2828	MOSFET Driver	2A output, 14ns rise and fall time, 24ns prop delay, inverting	Drives FETs for high-voltage transformer	TPS2829 non-inverting version
TPS3836	Voltage Supervisor	220nA supervisor with 10ms/200ms selectable delay time	Circuit initialization and timing supervision	TPS3809
TPS61042	White LED Driver	30V, 500mA switch boost converter, 1MHz switching frequency	Higher switching frequency requires smaller size inductor and capacitor	TPS61140
TPS717xx	Low-Noise Single-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS793xx, TPS795xx, TPS799xx
TPS718xx-yy	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719xx-yy
TPS780xx	LDO with DVS	Dynamic voltage scaling (DVS) with low I_Q 500nA	DVS voltage designed to operate with MSP430 to increase power savings	TPS78101
UCC38C4x	PWM Controller	14.9/9V on/off UVLO thresholds, 1MHz frequency, 50% duty cycle		UCC3804, UCC3809
UCD7100	Digital Control Driver	Adjustable current limit, 3.3V, 10mA internal regulator	Applications requiring fast local peak current limit protection	
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, Flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2431	System-on-Chip Solution for Zigbee location engine	CC2431 has 32/64/128 KB hardware AES encryption engine, excellent selectivity, blocking performance and hardware location	Ideal for battery operated systems;suitable for proprietary and ZigBee systems; adds location awareness and accuracy of 3 to 5 meters	
CC2530/31	Second Generation 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 SOC for quick time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity and blocking performance systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	

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

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

Medical Imaging

Overview

Medical imaging technology is continually evolving and advancing, all with the goal of improving patient care. TI's complete analog signal chain, power management, interface and embedded processing portfolios empower innovation in medical imaging by:

- Enabling faster, more accurate diagnostic results.
- Increasing the speed of delivery and availability of medical care worldwide.
- Improving accessibility and affordability of end equipments.

There are two prevalent trends in semiconductor innovation for the medical imaging market:

- Increased performance driven by the need for higher image quality.
- Decreased power consumption and size to allow equipment designs that are more portable, accessible and affordable.

TI's large portfolio of catalog and application-specific semiconductor products addresses major medical imaging modalities such as ultrasound, computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET) and digital X-ray, as well as newer innovative modalities such as hyperspectral imaging, optical coherence tomography (OCT), or not even yet envisioned imaging solutions.

Power continues to be a key concern for all of these modalities, as well as for medical applications overall, so we have dedicated a chapter to it towards the end of this section.

For more information on TI's offering for Medical Imaging, please visit *www.ti.com/medicalimaging*

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 embedded processors and analog products facilitate advanced ultrasound system designs with low power consumption and high performance, yielding portability with high-quality images.

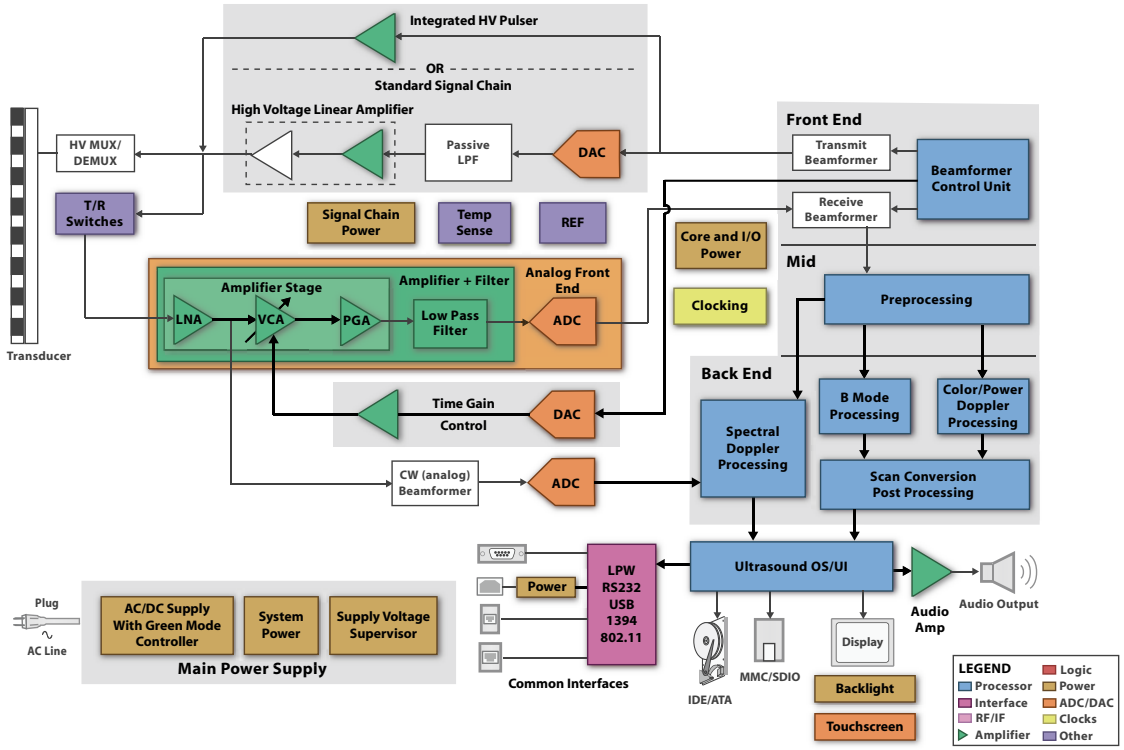
Medical and industrial ultrasound systems use focal imaging techniques to achieve imaging performance far beyond a single-channel approach. By using an array of receivers, TI's latest products for ultrasound enable high definition images through time shifting, scaling and intelligently summing echo energy. 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 parts 50 percent smaller than competitive solutions, with low power and low noise for superior image quality.
- The main function of T/R switches is to prevent high-voltage pulses from damaging the receive electronics.The TX810, an eight-channel integrated T/R switch, is designed to address designers' need to build smaller portable ultrasound systems while speeding time to market.
- The transmit beamformer, high-voltage (HV) pulser and HV multiplexer form the transmit path responsible for the pulse-excitation of transducer elements. The TX734 is an integrated, quad-channel, ±90-V pulser with active damping that reduces noise and minimizes size.

Embedded processors

- TMS320C6474 and TMS320C6455 high-performance DSPs are suitable for ultrasound processing such as B-mode imaging, color Doppler, speckle reduction, 3-D/4-D and other processing and filtering algorithms.
- OMAP35x SOCs are well suited to handle the operating system, connectivity and user interface require-ments in portable and hand-held ultrasound systems, while also being capable of handling processing algorithms like color scan conversion.

These products, along with TI's power management products, clocks and interfaces, provide a full signal chain portfolio of targeted integrated circuit solutions for ultrasound.

View the "Flexible Design, Low Power for Ultrasound Systems" video at:
www.ti.com/ultrasoundvideo

TI's AFE5851 analog front end was named a best product in the 2009 Design News Golden Mousetrap awards.

Integrated 8- and 16-Channel Analog Front Ends
AFE5801, AFE5851

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/AFE5801** or **www.ti.com/sc/device/AFE5851**

Key Features

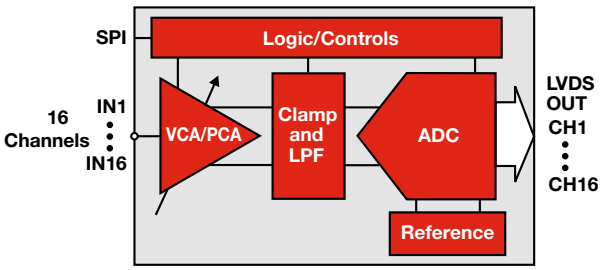
- Integrated VCA, PGA, LPF, 12-bit 65-MSPS ADC
- AFE5801:
  - 8 channels
  - 50mW per channel at 30MSPS 58mW per channel at 50MSPS
- AFE5851:
  - 16 channels
  - 39mW per channel at 32.5MSPS
- Digital gain control removes external DAC for smaller footprint and minimized noise
- Packaging: 9 x 9mm QFN

Applications

- Ultrasound

The AFE5851 is the first 16-channel AFE available for the ultrasound market. The device features 39mW/channel at 32.5MSPS and contains 16 variable-gain amplifiers (VGAs), followed by eight 12-bit, 65MSPS analog-to-digital converters (ADCs). Each ADC is shared between two VGAs and each VGA differential output is sampled at alternate clock cycles to optimize power dissipation. The ADC has scalable power consumption to enhance the lower power with lower sampling rates. The high channel count and low-power features of the AFE5851 allow for increased channel density in handheld ultrasound systems.

Both the AFE5851 and AFE5801 can be preceded by an off-chip low-noise amplifier (LNA), which can be on the probe or be a transformer. This new architecture enables customers to have more than 40 percent less power and a 70 percent smaller analog front-end footprint for hand-held ultrasound systems.



AFE5851 functional diagram.

Ultrasound

Fully Integrated 8-Channel Analog Front Ends
AFE5804, AFE5805

TI's AFE5805 analog front end won Electronic Product Design's e-Legacy award.

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/AFE5804** or **www.ti.com/sc/device/AFE5805**
View the "AFE5805 8-Channel Analog Front-End for Ultrasound" video at: **www.ti.com/afe5805video**

Key Features

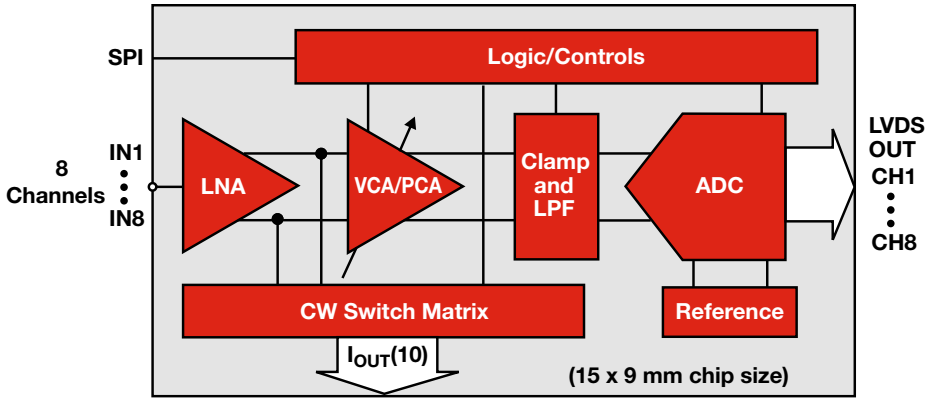
- Integrated LNA, VCA, PGA, LPF, 12-bit 50MSPS ADC
- AFE5805
  - 122mW per channel at 40MSPS
  - 0.85nV/√Hz at 2MHz
  - 250mV_{pp} linear input range
- AFE5804
  - 101mW per channel at 40MSPS
  - 1.23nV/√Hz at 2MHz
  - 280mV_{pp} linear input range
- LNA fixed gain: 20dB
- VCA gain can vary over a 46dB range with a 0 to 1.2V control voltage
- PGA programmable for gains of 20dB, 25dB, 27dB and 30dB
- Packaging: 135-pin 15 x 9mm BGA

Applications

- Ultrasound

The AFE5804 and AFE5805 are integrated analog front-end solutions designed specifically for mid-range to portable ultrasound systems. The AFE5804 features mode control for power/noise optimization. It has the low-power performance at 101mW per channel while maintaining superior image quality. With a superior low-noise feature of 0.85nV/√Hz at 2MHz, the AFE5805 achieves performance suitable not only for portable equipment but also for high-channel-density, mid-range ultrasound systems.

The AFE5804 and AFE5805 consist of eight channels, including a low-noise amplifier (LNA), voltage-control attenuator (VCA), programmable-gain amplifier (PGA), low-pass filter (LPF) and 12-bit, 50MSPS analog-to-digital converter (ADC) with LVDS data outputs. The LVDS outputs of the ADC reduce the number of interface lines to an ASIC or FPGA, thereby enabling the high system integration densities desired for portable systems.



AFE5805 ultrasound analog front end.

Ultrasound

TI's TX810 was selected as a 2010 Design News Golden Mousetrap Best Product Finalist.

Integrated, 8-Channel T/R Switch

TX810

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/TX810**
View the "First Integrated Ultrasound T/R Switch" video at: **www.ti.com/tx810video**

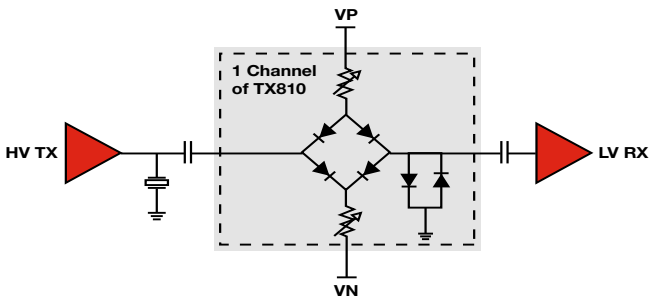
Key Features

- Integrates a protection diode bridge and clamp diodes for each of its eight channels
- Programmable bias currents
  - 3-bit interface used to program a 7mA range of bias currents
  - Power-down mode to reduce power consumption
- Optimized insertion loss maintains integrity of input/output signal at 400Ω load with 0.9dB at 7mA bias current and 1.3dB at 1mA bias current

Applications

- Ultrasound

The TX810 addresses designers' need to build smaller portable ultrasound systems, while speeding time to market. The TX810 integrates a protection diode bridge and clamp diodes for each of its eight channels to prevent the high-voltage pulses of the transmitter from damaging the receive electronics of the ultrasound system. The device saves more than 50 to 75 percent board space over discrete solutions in portable to mid-range ultrasound systems, depending on T/R architectures, and the component reduction and easier handling brings higher reliability to designs.



TI's TX734 was elected as a finalist for Electronic Product Design's 2009 e-Legacy awards for advancing the future of medical imaging.

±100V, 2A, Quad-Channel Pulser

TX734

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/TX734**
View the "TX734 Product Overview" video at: **www.ti.com/tx734video**

Key Features

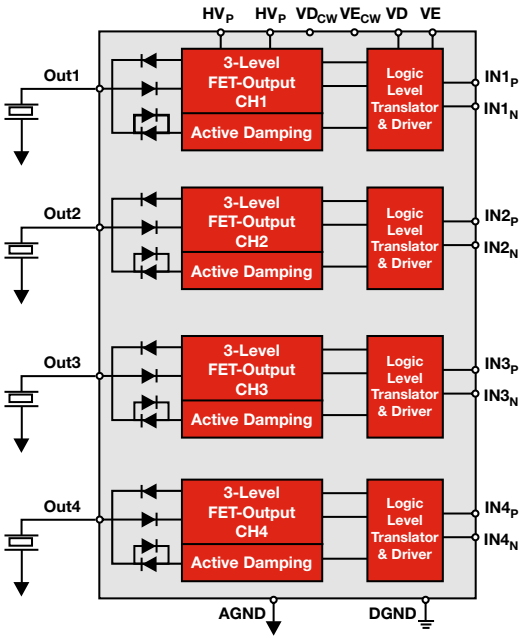
- Quad channel
- Voltage: ±100V
- Peak output current: ±2A
- Active damping
  - True 3-level RTZ
  - Internally activated
- Imaging output frequency: Up to 20MHz
- Logic inputs: 2.5V to 5V
- Low HD2 distortion: -40dBc, at 5MHz

Applications

- Ultrasound

The TX734 addresses the needs of high-density systems that require a three-level, high-voltage pulse pattern by integrating four channels of level translators, drivers, high-voltage output stage and active damping into a 64-pin, 9mm x 9mm QFN package.

Active damping, also called fast clamping to ground, allows for a clean three-level return-to-zero (RTZ) waveform. This improves pulse symmetry and delivers low second order distortion of -40dB. The active damping feature in the TX734 prevents noise from being injected into the transducer, which improves signal sensitivity by at least 5dBc, resulting in better image quality.



Ultrasound

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

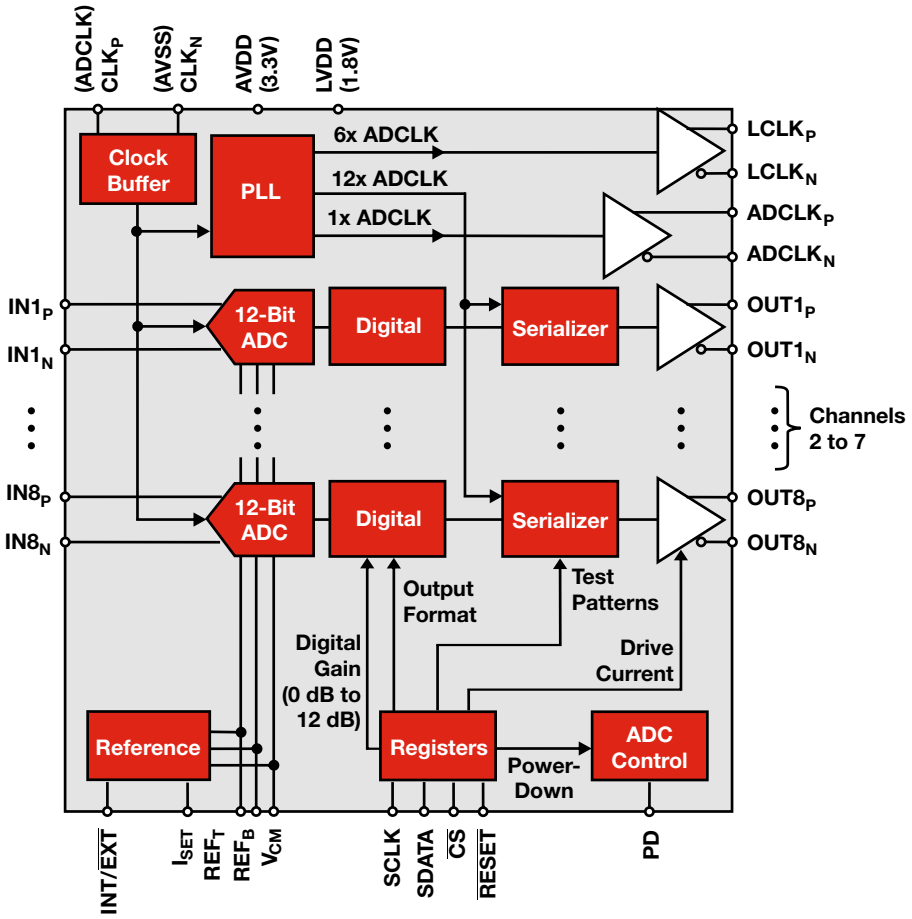
- 8-channel 12- or 10-bit ADCs in one small 64-pin QFN package
  - ADS5281 also available in 80-pin TQFP pin-compatible to ADS527x
- 77mW per channel at 65MSPS
- 64mW per channel at 50MSPS
- 70dB SNR for 12-bits at 10MHz IF
- 1/f (flicker) noise suppression
- Up to 6dB overload recovery in one clock 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.

Ultrasound

8-Channel Variable-Gain Amplifier with Low-Noise Amplifier

VCA8500

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/VCA8500**

Key Features

- Ultra-low power: 65mW/channel
- Low noise: 0.8nV/√Hz
- Low-noise amplifier (LNA):
  - 20dB fixed gain
  - 250mV$_{PP}$ linear input range
- Variable-gain amplifier:
  - Gain control range: 46dB
  - Selectable PGA gain: 20/25/27/30dB
  - Fast overload recovery
  - Output clamping control

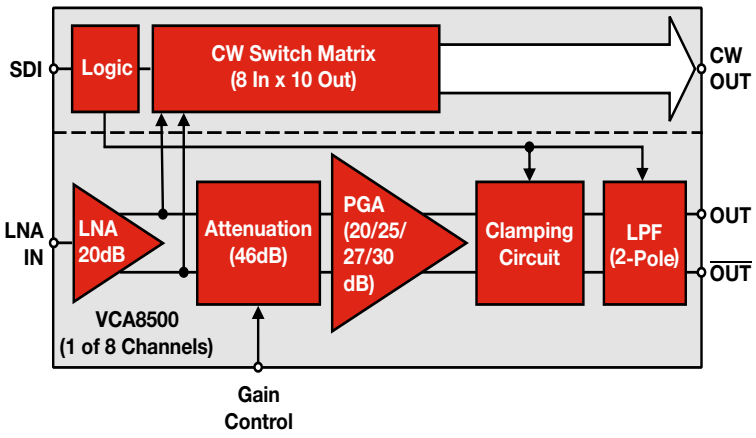
Applications

- Medical imaging:
  - Ultrasound
  - Sonar

The VCA8500 is an eight-channel variable-gain amplifier consisting of a low-noise amplifier (LNA) and a variable-gain amplifier (VGA). This combination, along with the device features, makes it ideal for a variety of ultrasound systems.

The ultra-low-power spec of 65mW/channel is optimized for portable ultrasound systems requiring low power consumption and for mid-range systems increasing their number of channels per system while maintaining stringent low-power requirements.

The low-noise spec of 0.8nV/√Hz, the LNA fixed gain at 20dB and VGA gain control range at 46dB provide excellent noise- and signal-handling characteristics for improving image quality in ultrasound systems.



Functional diagram.

Ultra-Wideband, Current-Feedback Op Amp with Disable

OPA695

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/OPA695**

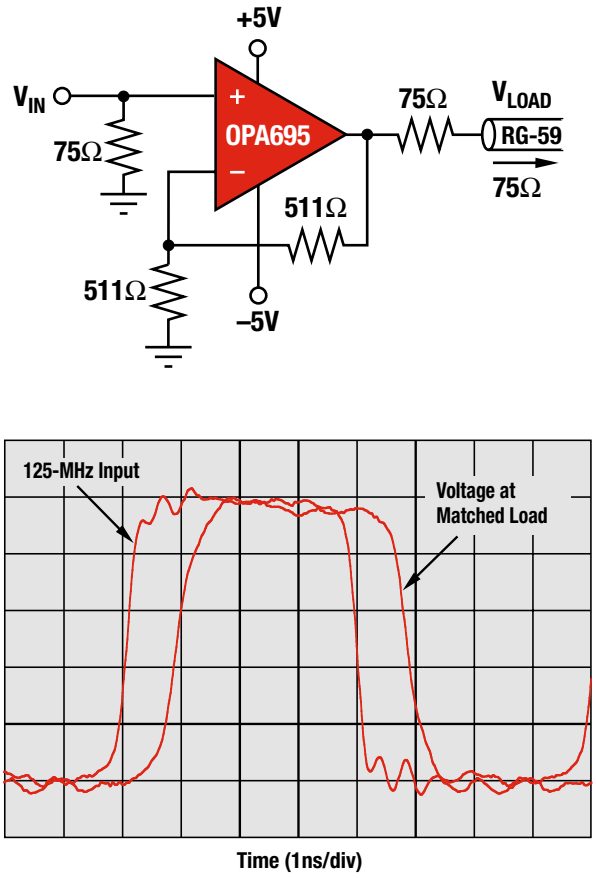
Key Features

- Gain = +2 bandwidth (1400MHz)
- Gain = +8 bandwidth (450MHz)
- Output voltage swing: ±4.2V
- Ultra-high slew rate: 4300V/µs
- Low power: 129mW
- Low disabled power: 0.5mW
- Packaging: SOT23-6, SO-8

Applications

- Very wideband ADC driver
- Low-cost precision IF amplifier
- Broadband video line driver

The OPA695 is a single-channel, very broadband, current feedback operational amplifier. As a gain of +2V/V line driver, it offers 1.4GHz bandwidth with 2900V/µs slew rate. These give a 0.8ns rise time for a 2V output step — more than adequate for the highest speed video requirements. Single supply operation extends from +5V to +12V to span the most popular supplies used for fixed gain IF amplifiers. The OPA695's low 12.9mA supply current is precisely trimmed at +25°C. This trim, along with a low temperature drift, gives low system power over temperature.



Video line driver with a gain of +2V/V and typical pulse-response waveforms.

Ultrasound

Dual, Wideband, Current-Feedback Op Amp with Disable

OPA2695

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/OPA2695**

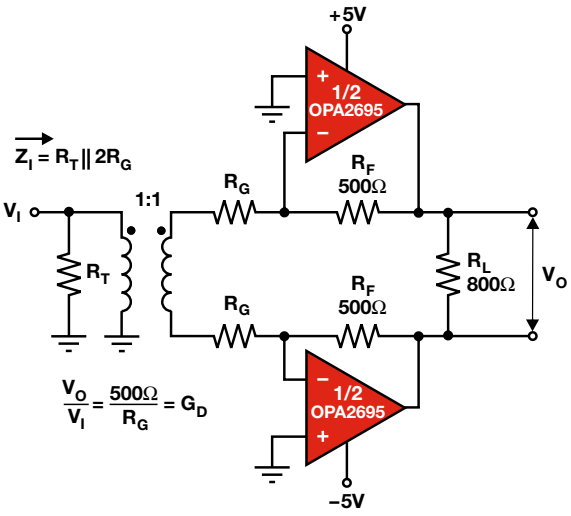
Key Features

- Gain = +2V/V bandwidth (850MHz) or +8V/V bandwidth (450MHz)
- Slew rate: 2900V/µs
- Output voltage swing: ±4.1V
- Low quiescent current: 12.9mA/channel
- Low disable current: 200µA/channel
- Single (OPA695) and triple (OPA3695)
- Packaging: SO-8 (without disable), QFN-16 (with disable)

Applications

- Very wideband ADC drivers
- Portable instruments
- Active filters
- Low-cost precision IF amplifiers

The OPA2695 is a wide-bandwidth, current-feedback amplifier with disable that features an exceptional 2900V/µs slew rate and low 1.8nV/√Hz input voltage noise. The device has been optimized for high gain operation. The pinout provides symmetrical input and output paths, making the OPA2695 well suited as a differential ADC driver. The low 12.9mA/channel supply current is precisely trimmed at +25°C. This trim, along with a low temperature drift, gives low system power over temperature.



Differential driver.

Dual, Low-Power, Wideband, Voltage-Feedback Op Amp with Disable

OPA2889

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/OPA2889**

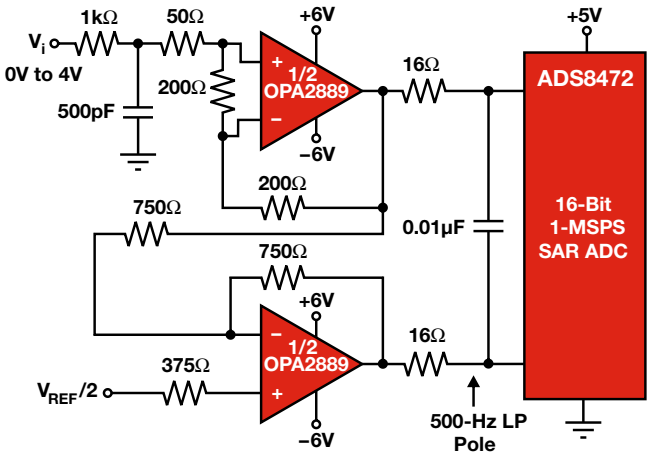
Key Features

- Flexible supply range:
  - +2.6V to +12V single supply
  - ±1.3V to ±6V dual supply
- Slew rate: 250V/µs
- Output voltage swing: ±4V
- Wideband ±5V operation: 60MHz (G = +2V/V)
- Low quiescent current: 460µA per channel
- Low disable current: 18µA
- Packaging: SO-8, MSOP-10

Applications

- High-speed imaging channels
- ADC buffer
- Portable instruments
- Active filters

The OPA2889 is a dual, wideband, low-power amplifier with disable. The new internal architecture offers slew rate and full-power bandwidth previously found only in wideband current-feedback amplifiers. These capabilities, coupled with a very low quiescent current of only 460µA per channel, make it very well-suited for portable instrumentation. Operating from a ±5V supply, the OPA2889 can deliver a ±4V output swing with over 40mA drive current and 60MHz bandwidth, making it ideal as an RGB line driver, single-supply analog-to-digital (ADC) input driver or low-power twisted-pair line receiver.



Low-power, DC-coupled, single-to-differential driver for ≤100-kHz inputs.

Ultrasound

TMS320DM6446 Digital Media Processors Featuring DaVinci™ Technology

TMS320DM6446

Get samples, datasheets, tools and application reports at: **www.ti.com/davinci**

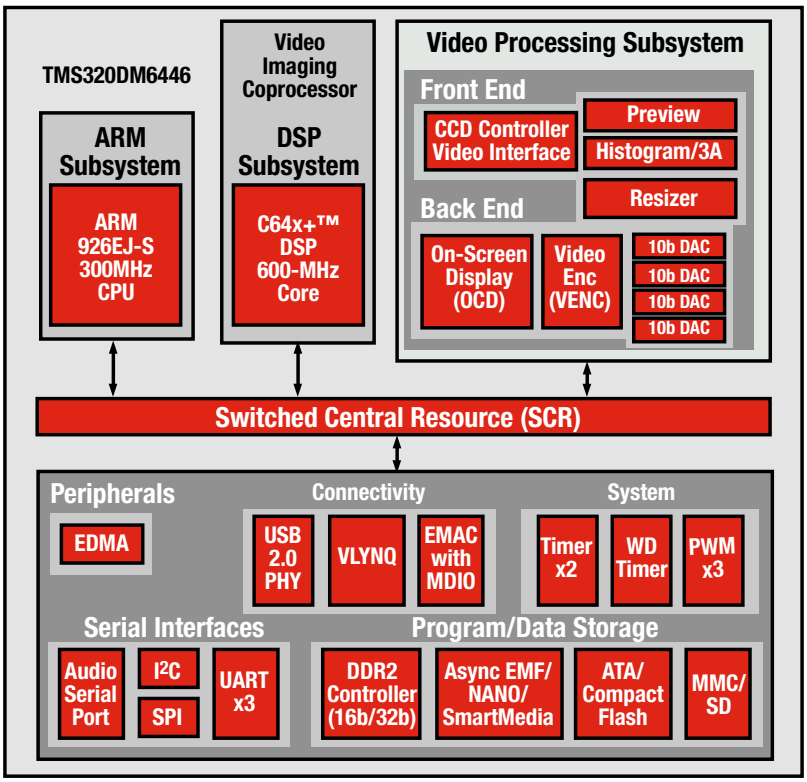
Key Features

- High-performance digital media SoC
  - 594MHz C64x+™ clock rate
  - 297MHz ARM926EJ-S clock rate
  - Eight 32-bit C64x+ instructions/cycle
  - 4752 C64x+ MIPS
  - Fully software compatible with C64x+/ARM9
- Load-store architecture with non-aligned support
- Sixty-four 32-bit general-purpose registers
- Instruction packing reduces code size
- Video processing subsystem
  - CCD and CMOS imager interface
  - Preview engine for real-time image processing
  - Glueless interface to common video decoders
- Embedded trace buffer (ETB11) with 4KB memory for ARM9 debugging

Applications

- Medical imaging
- Digital media
- Networked media encode/decode

TMS320DM6446 digital media processors are ideal for ultrasound and various other medical imaging products. TMS320DM6446 digital media processors are highly integrated SoCs based on an ARM926EJ-S processor and the TMS320C64x+™ DSP core. They leverage TI's DaVinci™ technology to meet the networked media encode and decode application processing needs of next-generation embedded ICs. The TMS320DM6446/41 enable developers to quickly bring to market devices featuring robust operating systems support, rich user interfaces, high processing performance and long battery life through the maximum flexibility of a fully integrated mixed-processor solution.



TMS320DM6446 block diagram.

Ultrasound

Six-core TMS320C6472 Ideal for High-Performance Stringent Power Budget Applications
TMS320C6472

Get samples and datasheets at: **www.ti.com/sc/device/TMS320C6472**

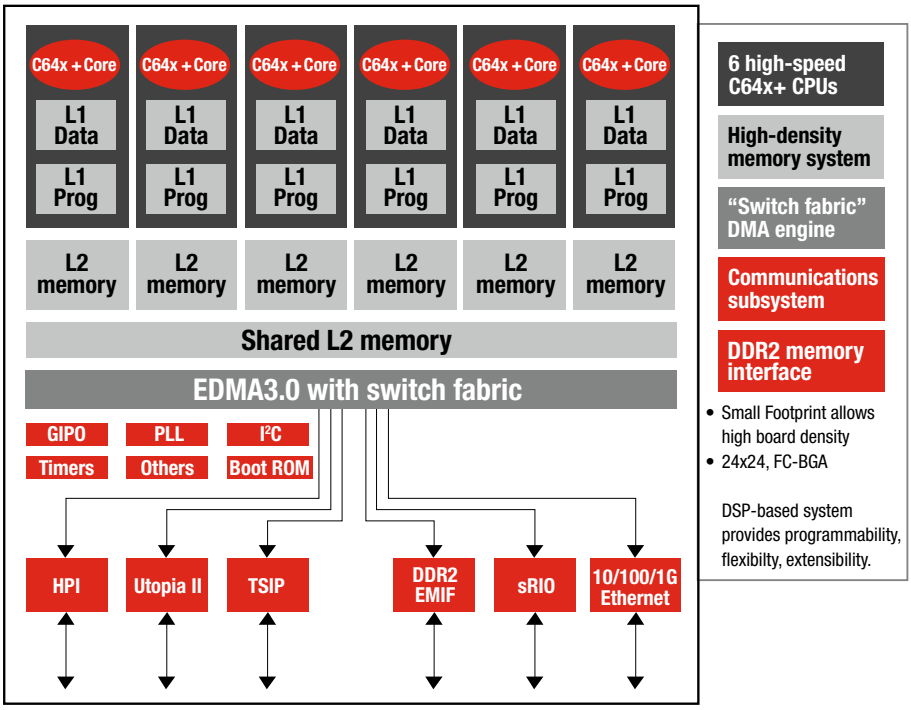
Key Features

- Integrates six on-chip TMS320C64x+ DSP cores on a single chip
- 500/625/700MHz speed versions
- Eight 32-bit instructions/cycle
- 4000MIPS/MMACS (16-bits) at 500MHz
- Shared memory architecture 768K-byte
- Local L2 RAM per C64x+ 608K-byte
- Dedicated SPLOOP Instruction
- Switch fabric DMA engine
- Serial/deserializer (SERDES) interfaces
- DDR2 memory interface: 533Mhz
- 10/100/1G ethernet
- High Performance Interface (HPI)
- 24 x 24mm FC-BGA package

Applications

- Ultrasound
- Medical imaging
- High performance systems
- Projects with high performance/ stringent power budgets

The TMS320C6472 multi-core digital signal processor (DSP) saves cost, power, and board space by integrating six industry-leading cores running at up to 700Mhz each on a single die. The C6472 delivers up to 4.2Ghz of raw DSP performance that consumes only 60 percent of the power and occupies 80 percent less board space than six individual TMS320C6415 DSP's. At 3.7 watts per device, it offers even greater power savings than compared to general purpose processors in the same performance range. A common key requirement of many high performance applications is the availability of large on-chip memories to handle vast amounts of data during processing. With 768K-Byte of shared RAM and 608K-Byte local L2 RAM per C64x+ Mega-module, the TMS320C6472 device can eliminate the need for external memory, thereby reducing system power dissipation and system cost and optimizing board density.



TMS320C6472 block diagram.

Ultrasound

High-Performance Processor Integrates Three 1GHz Cores

TMS320C6474

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320C6474**

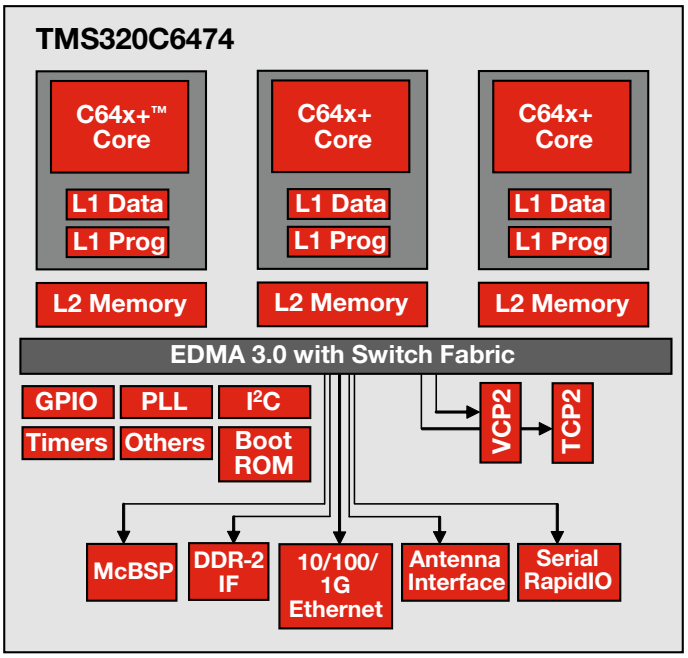
Key Features

- Delivers 3x the raw DSP processing performance
- Gain in raw performance: 50 percent per watt
- Integrates three 1.2GHz cores on a single chip
- Multiple-channel processing capabilities
- Serial/deserializer (SERDES) interfaces
- L1 program and L1 data memory per core: 32KB
- DDR2 memory interface: 667MHz
- Process shrink to 65nm feature size

Applications

- Medical imaging
- High-performance systems
- Multichip system designs
- Projects with stringent power budgets

The TMS320C6474 multicore digital signal processor (DSP) saves cost, power and board space by integrating three industry-leading cores running at 1GHz, each on a single die. The C6474 delivers up to 1.2GHz of raw DSP performance that consumes one-third less power at two-thirds less DSP cost over discrete processing solutions. This DSP provides significant system integration for designers using DSP farms in various applications.



TMS320C6474 DSP block diagram.

TMS320C645x DSP Generation, Fixed-Point Highest Performance DSPs

TMS320C6455

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320C6455**

Key Features

- Based on the new TMS320C64x+™ core 720MHz, 850MHz, 1GHz, 1.2GHz
- Memory:
  - 32KB L1D, 32KB L1P cache/SRAM
  - 2MB L2, 256K cache/SRAM, remainder SRAM only
- Acceleration:
  - Viterbi decoder coprocessor (VCP)
  - Turbo decoder coprocessor (TCP)
- Peripherals:
  - Serial RapidIO: 10GbPs full duplex
  - Two EMIFs: 32-bit DDR2, 64-bit EMIF
  - Other high-bandwidth peripherals: Gigabit Ethernet MAC, UTOPIA, PCI-66, HPI

TMS320C64x+™ DSPs (including the TMS320C6455) are the highest performance, fixed-point DSP generation in the TMS320C6000™ DSP platform. The C6455 IC is based on the third-generation, high-performance, advanced VelociTI™ very-long instruction-word (VLIW) architecture developed by TI. This allows these DSPs to be used for applications including medical imaging, video and telecom infrastructure, imaging, and wireless infrastructure (WI). The C64x+™ ICs are upward code-compatible from previous ICs that are part of the C6000™ DSP platform.

Applications

- Ultrasound
- Digital X-ray
- Medical imaging

Ultrasound

Industry's Lowest Power Floating-Point DSPs

TMS320C6747

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320C6747**

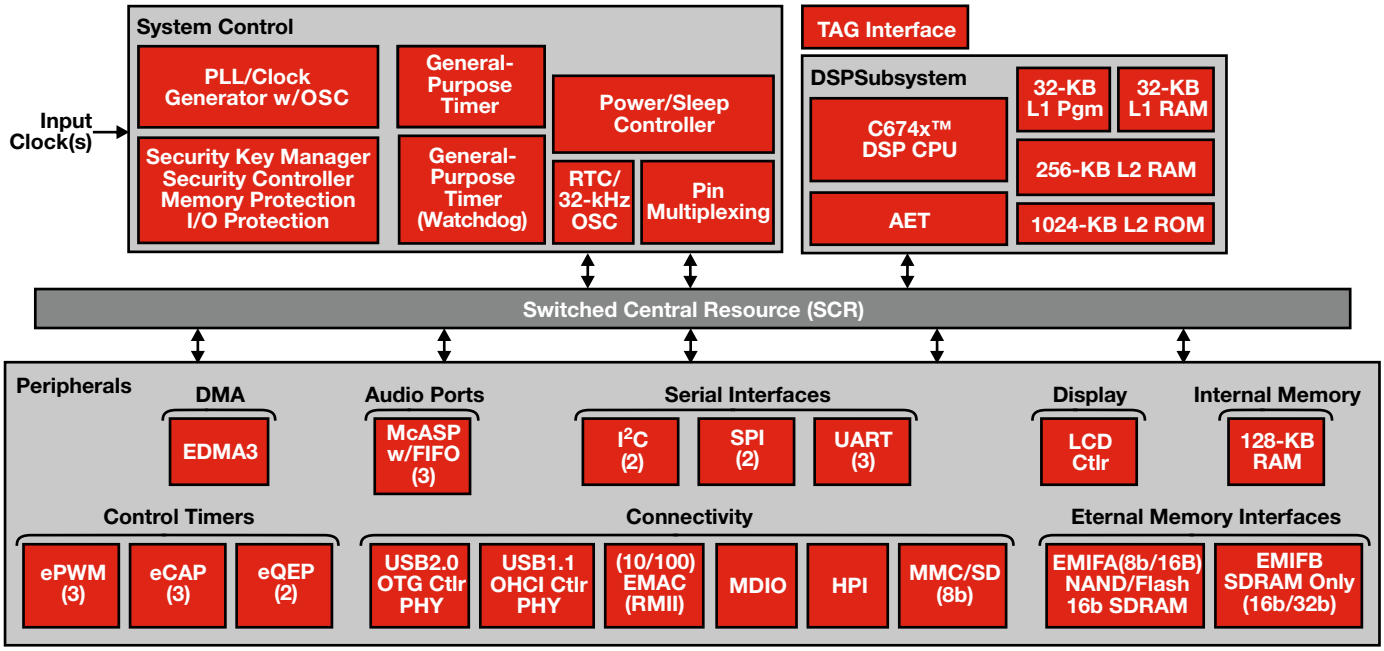
Key Features

- Industry's lowest power floating-point DSPs
- High precision and wide dynamic range enabled through the 32-/64-bit accuracy of the floating-point DSP core
- Portability for traditionally wired applications through low power and rich connectivity peripherals
- Reduced system cost through high feature integration and low pricing
- Up to 20x lower standby power and one-third the power consumption of existing floating-point devices

The TMS320C6747 DSP combines low power and high precision to give designers the freedom to bring portability to medical and other applications requiring the precision, wide dynamic range and time-to-market benefits of floating-point DSPs. Using three times less power than existing floating-point DSPs, C674x devices support 32-bit single-precision and 64-bit double-precision floating-point architecture and are the industry's lowest power floating-point DSPs.

Applications

- Portable ultrasound
- Industrial
- Conference phones
- Music effects



TMS320C6747 DSP block diagram.

Ultrasound

Digital Media Processor
TMS320DM355

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/TMS320DM355**

Key Features

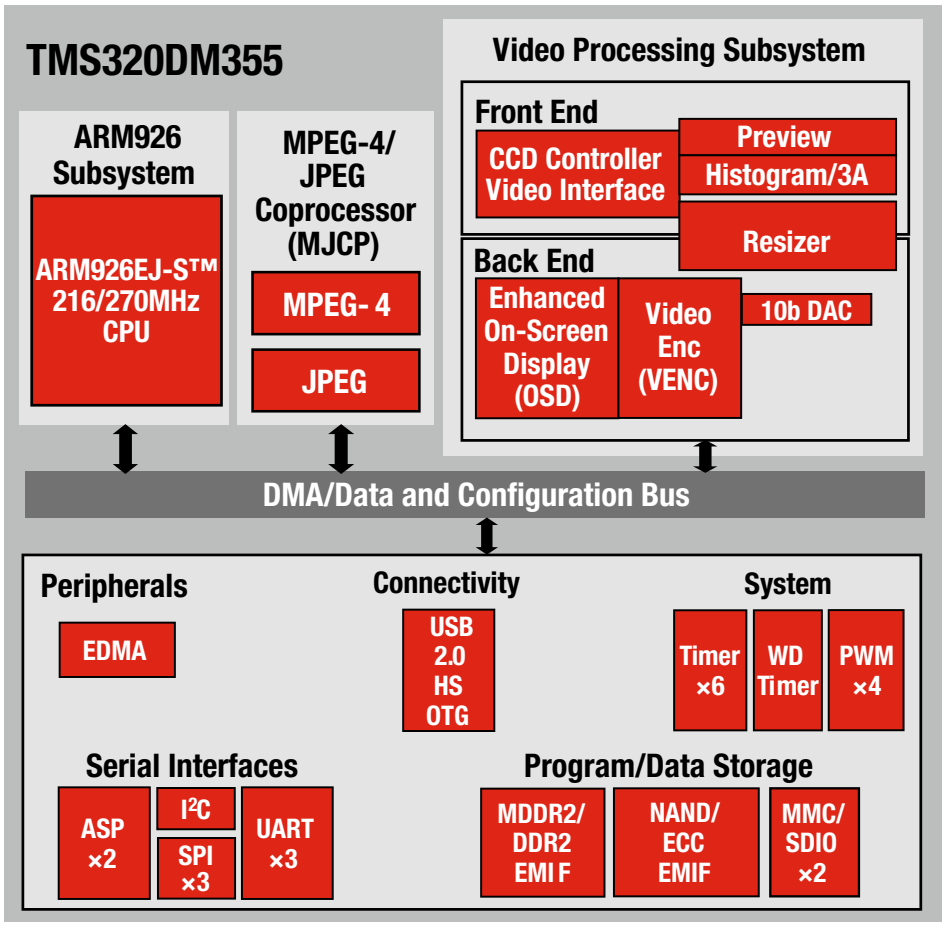
- High-performance digital media processor
- Fully software-compatible with ARM9™
- 216MHz and 270MHz ARM926EJ-S™ core
- TI's DaVinci™ software technology
- MPEG-4/JPEG coprocessor
- Video processing subsystem
- 16-bit-wide DDR/mDDR SDRAM EMIF with 256MB address space
- MMC and SD/SDIO flash card interface
- USB, UART, SPI and I²C peripherals
- Up to 104 configurable general-purpose I/Os (GPIOs)

Applications

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

The TMS320DM355 is a highly integrated, programmable platform ideal for developing low-cost portable medical video applications. With an ARM9™ processor at its core, the DM355 high-performance digital media system-on-chip (DMSoC) leverages TI's DaVinci™ technology to offer high-performance video MPEG-4 HD (720p) codecs and JPEG codecs to users developing affordable, high-quality, low-power video solutions. The DM355 has a video-processing subsystem (VPSS) with a configurable video-processing front end (VPFE) to interface with CCD/CMOS imager modules or video decoders; a configurable video-processing back end (VPBE) used for hardware on-screen display (OSD) support; and composite NTSC/PAL and digital LCD output. In addition, the DM355 peripheral set includes a range of interfaces such as USB, I²C, audio serial ports (ASPs), UART, serial peripheral interface (SPI), external memory interface (EMIF) and GPIOs. With a complete range of ARM® development tools including C compilers, assemblers and a Windows® debugger interface for visibility into source-code execution, the DM355 offers a low-cost portable video alternative for medical devices.

For medical applications that do not require video, the lower-cost DM335 is a good alternative without the video acceleration.



TMS320DM355 processor.

Ultrasound

High-Performance Applications Processor

OMAP3530

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/OMAP3530**

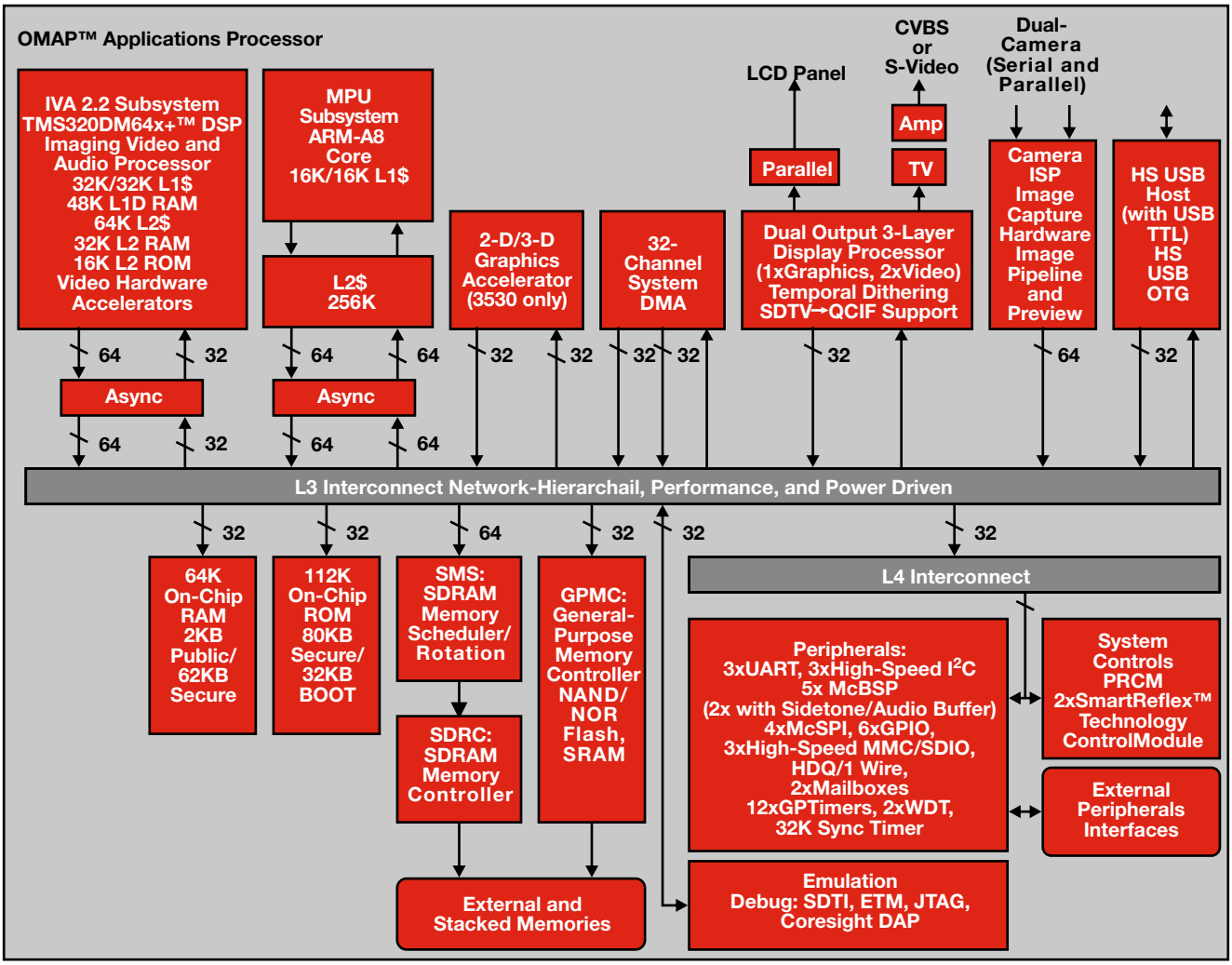
Key Features

- OMAP3530/25 applications processor
- Advanced very-long-instruction-word (VLIW) TMS320C64x+™ DSP core
- C64x+™ L1/L2 memory architecture
- C64x+ instruction set features
- ARM® Cortex-A8 core
- ARM Cortex-A8 memory architecture
- 112KB ROM
- 64KB shared SRAM

OMAP3530 and OMAP3525 are high-performance applications processors based on the enhanced OMAP™ 3 architecture. The OMAP 3 architecture is designed to provide best-in-class video, image and graphics processing sufficient to support streaming video, 2-D/3-D mobile gaming, video conferencing and high-resolution still image. It also supports video capture in 2.5G wireless terminals, 3G wireless terminals, rich multimedia-featured handsets and high-performance personal digital assistants (PDAs).

Applications

- Ultrasound
- Ultra mobile devices
- Portable data collection
- Digital video camera



OMAP3530 functional diagram.

Ultrasound

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Analog Front Ends				
AFE5801 **Page 81*	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 **Page 82*	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 **Page 82*	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 **Page 81*	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				
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
OPA695 **Page 86*	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 **Page 87*	Dual, Wideband, Current-Feedback Operational Amp	±4.2V output voltage swing, low quiescent current, low disable current	Optimized for high gain operation	
OPA2889 **Page 87*	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
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/√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 **Page 85*	8-Channel Ultrasound Front End	Complete with LNA, VCA and LPF; low noise and power: 0.8nV/√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/√Hz	Best-in-class noise	VCA8500

**For additional product information see designated page number.*

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

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Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters				
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 *Page 84	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 *Page 84	High-Speed ADC	Ultra-low-power, 8-channel, 12-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281
ADS5287 *Page 84	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
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				
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

**For additional product information see designated page number.*

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

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Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
References (continued)				
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
Processors				
OMAP3530 *Page 93*	Applications Processor	ARM® Cortex A-8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at handheld power levels	OMAP3503, OMAP3515, OMAP3525
TMS320C6452	DSP	900MHz, 1.4MB L2 cache, 2x SGMII/Gigabit EMAC	High-performance DSP with improved system cost	
TMS320C6455 *Page 90*	DSP	1.2GHz, SRIO, 2MB RA	High-performance, fixed-point 16-bit processor	TMS320C6454BZTZ
TMS320C6472 *Page 89*	DSP	6x 700MHz C64x+ cores, 4.8MB RAM, SRIO, HPI	High-performance multiprocessor solution	
TMS320C6474 *Page 90*	DSP	3x 1.2GHz C64x+ cores, 3MB RAM, SRIO	High-performance multiprocessor solution	
TMS320C6745	DSP	1800MFLOPS, 256KB L2	Low cost floating point, combines C64x+ and C67x cores	TMS320C671x
TMS320C6747 *Page 91*	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 *Page 92*	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 *Page 88*	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
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
Power Management				
bq20z40-R1	SBS-Compliant Gas Gauge with Impedance Track™ Technology for use with BQ29330	Impedance Track Technology, Supports the Smart Battery SBSV1.1 specification	Provides better than 1% error over lifetime of Li-Ion and Li-Polymer Batteries	bq20Z95
bq24721	Battery Charge Management	Multichemistry and multicell sync switch-mode charger	High efficiency, pack and system protection functions	bq24105
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 – 12 Li-Ion cells in series, active cell balancing	bq76PL102

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Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (continued)				
DCH010505	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
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
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
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS386000	4-Channel Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808
TPS54317	DC/DC Converter	3.0 to 6.0V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	
TPS54350	DC/DC Converter	4.5 to 20V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS62110	DC/DC Converter	3.1 to 17V_{IN} 1.5A DC/DC with integrated switch FET, synchronization pin, enable, Low battery indicator, PFM mode	Very low noise/high efficiency	
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62420
TPS63000	Buck-Boost Converter	1.8A switch, automatic transition between step down and boost mode	Stable output voltage over entire entire V_{IN} range	TPS63010
TPS65073	PMU with charger and WLED	Integrates charger, WLED, DCDC and LDO.	Highest integration for portable applications	TPS650250
TPS727xx	Single Channel LDO	High PSRR/low noise/ultra low I_Q	Battery power applications	TPS717xx
TPS7A45xx	Single Channel LDO	High PSRR/low noise/ultra low I_Q	High Performance with V_{IN} < = 20V	TL1963xx
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat	TPS74301, TPS74801
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat	
UCD90120	12-Channel Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124
Pulsers and Switchers				
TX734 *Page 83	Quad-Channel, High-Voltage Ultrasound pulser	Quad, 3-level RTZ, ±100V, ±75V, 2A integrated ultrasound pulser	Low-noise operation	TX810
TX810 *Page 83	8-Channel Integrated T/R Switch	Eight bias current settings; eight power/performance combinations; accepts 200VPP input signals	Compact T/R switch; flexible programmability; easy power-up/down control; fast wake-up time; dual supply operation; optimized insertion loss	TX734
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
Toolkits				
STK-MED *Page 126	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® Discovery™ 4100	An optical semiconductor 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® Pico™ Kit	Projector Development Kit that fully integrates projection solutions for a vast array of portable medical devices	44.8x67.4x14.2mm^3, I^{2}C command interface	Well suited for incorporating digital projection into portable devices	DLP® Discovery™

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

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Ultrasound

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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; 400 m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	Second Generation 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 made easy for fast time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings; excellent selectivity and blocking performance	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery operated systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	

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

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

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.

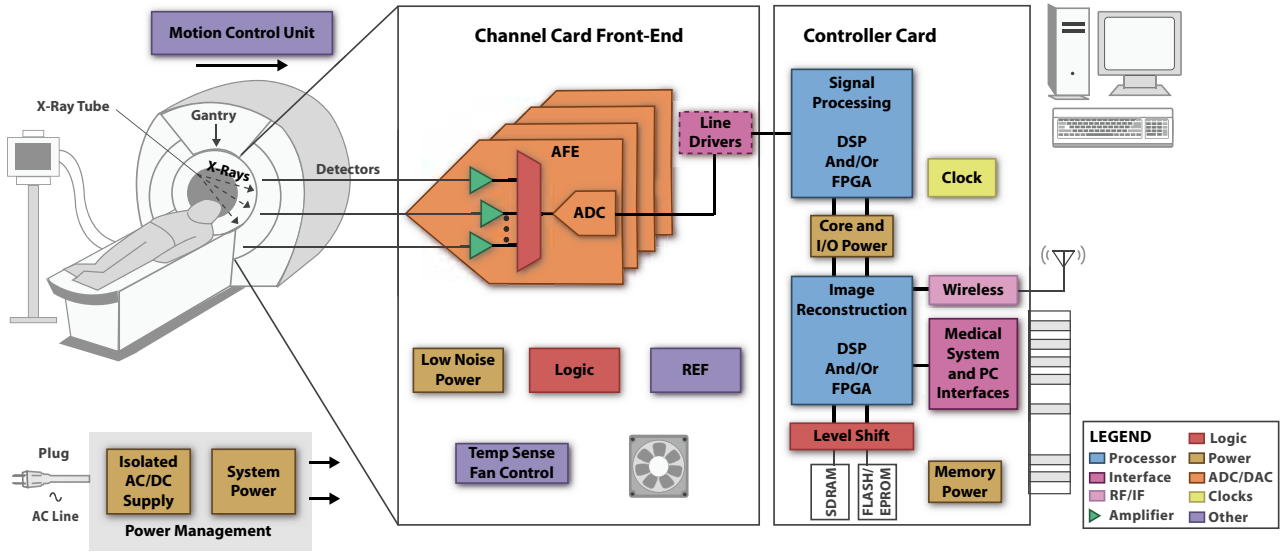
The detector system consists of a number of channel cards that have scintillator-photodiode solid state detectors. The X-rays interact with the scintillator and produce visible light, which is in turn converted into a current by the photodiode. The depth information along the direction of the X-ray beam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

- Channel card front end and control card subsystems, including data converters, processors, power management solutions and other analog products.
- 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

DDC232

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/DDC232**

Key Features

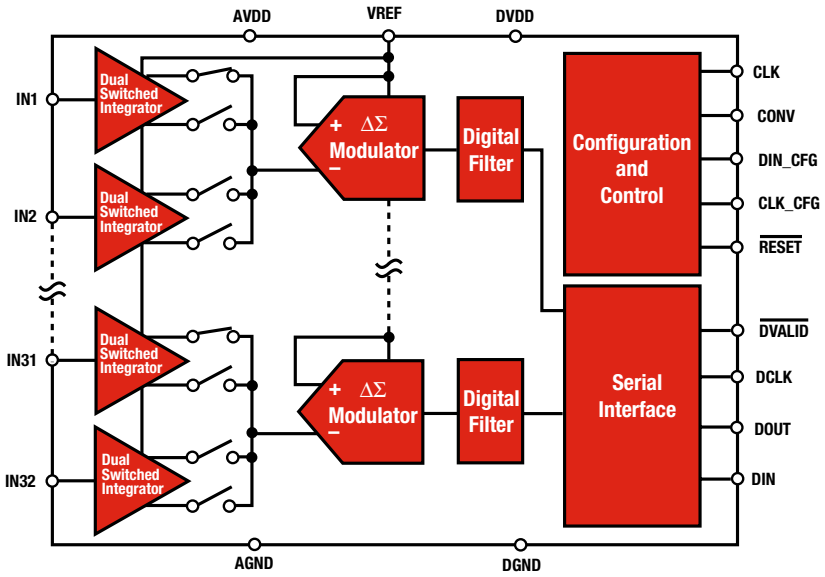
- Complete solution for measuring 32 photodiodes with 20-bit resolution
- Continuous charge collection
- Adjustable integration time: 160µs to more than 1s
- Programmable full scale: 12.5pC up to 350pC
- Low noise: 5ppm, rms
- Integral nonlinearity: ±0.025% reading ±1ppm FSR
- Single supply with 7mW/channel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

Applications

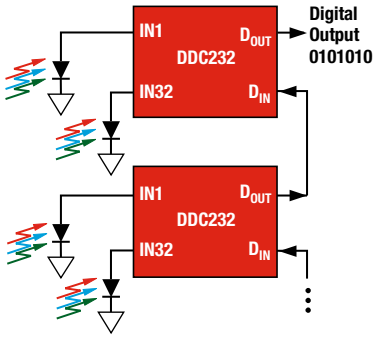
- CT scanners
- X-ray systems
- Photodiode sensor arrays

TI offers several products that can meet the needs of designers of medical imaging systems by enabling the measurement of low-level currents produced by the photodiode arrays within a computed tomography (CT) scanner.

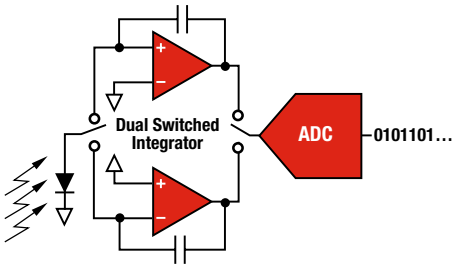
The DDC products are single-chip solutions for directly digitizing low-level currents from photodiode arrays in CT scanners. The dual-integrator front-end provides continuous charge collection. While one integrator is collecting the photodiode current, the other is being measured by the onboard 20-bit 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.



Photodiode measurement using the DDC232 ADC.



DDC architecture.

CT Scanners

Precision, High-Speed Transimpedance Amplifier
OPA380

Get datasheets and application reports at: **www.ti.com/sc/device/OPA380**

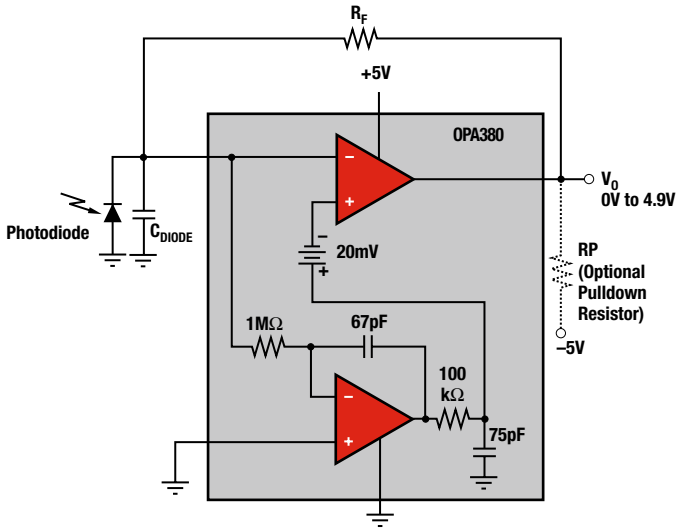
Key Features

- Over 1MHz TIA bandwidth
- Dynamic range: 5 decades
- Inherent long-term stability
- Output swing includes ground
- Very low 1/f noise
- Bias current: 50pA (max)
- Offset voltage: 2µV (max)
- Drift: 0.1µV°C
- Gain bandwidth: 90MHz
- Quiescent current: 6mA
- Supply range: 2.7V to 5.5V
- Single and dual versions
- Packaging: MSOP-8 and SO-8

Applications

- CT scanner front end
- Precision current-to-voltage measurements
- Optical amplifiers
- Photodiode monitoring

The OPA380 transimpedance amplifier family provides high speed, high precision and long-term stability. It exceeds the offset, drift and noise performance that conventional JFET op amps provide.



OPA380 functional block diagram.

18-Bit, 1MSPS, Differential Input, microPower ADC with Parallel Interface
ADS8482

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/ADS8482**

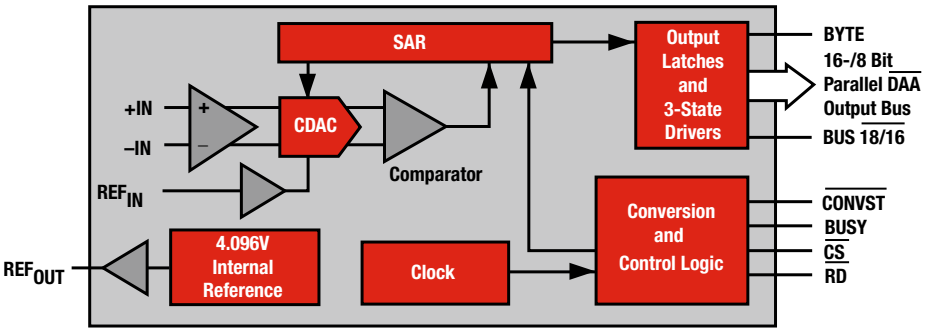
Key Features

- Sample rate: 0 to 1MHz
- INL: ±1.2LSB (typ); ±2.5LSB (max)
- DNL: +0.75/–0.6LSB (typ); +1.5/ –1LSB (max)
- 18-bit NMC ensured over temperature
- Offset error: ±0.05mV
- Offset error drift: ±0.05ppm/°C
- Zero latency
- Wide digital supply: 2.7V to 5.25V
- Low power: 225mW at 1MSPS
- Packaging: 48-lead QFN, 7 x 7mm

Applications

- Medical instruments
- Transducer interface
- High-accuracy data acquisition systems

The ADS8482 is an 18-bit, 1MSPS ADC with an internal 4.096V reference and a pseudo-bipolar, fully differential input. It features a full 18-bit interface, a 16-bit hold option where data is read using two read cycles or an 8-bit bus option using three read cycles. Other features include 99dB SNR, –121dB THD, 123dB SFDR, onboard reference with 6ppm/°C drift and onboard reference buffer.



ADS8482 functional block diagram.

CT Scanners

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifier				
OPA2211	Lowest Power, 1.1nV/√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 *Page 101	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/√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 *Page 101	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 *Page 100	32 Channels	12.5 to 350pC full-scale	Up to 6kSPS data rate, 7mW/Ch	BGA-64
References				
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
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
TMS320C6474	DSP	3x 1GHz C64x+™ DSP cores, 3MB RAM, SRIO	High-performance multiprocessor solution	

For additional product information see designated page number. To view more system block diagram compatible products, visit* ***www.ti.com/medical*

CT Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
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	
Power Management				
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
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS386000	4-Channel Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808
TPS40020	2.25V to 5.5V DC/DC Controller	Synchronization pin, PG, enable	Eliminate beat noise/ceramic caps/FPGA/regulation from main power supply	TPS40042
TPS40057	8V to 40V DC/DC Controller	Synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/regulation from main power supply	TPS40200
TPS54317	DC/DC Converter	3.0 to 6.0V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54610/TPS54910
TPS54350	DC/DC Converter	4.5 to 20V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS6206x	Step-Down Converter	High frequency operation, 2x2 QFN package,power save mode	High efficiency, small solution size	TPS62290
TPS62110	Step-Down Converter	3.1V to 17V V_{IN}, 1.5A conversion, synchronization pin, Low battery indicator, power save mode	Very low noise/high efficiency	TPS62050
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62420
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74301, TPS74801
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	
UCD90120	12-Channel Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124

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

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

CT Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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; 400-m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
RF Systems-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	Second Generation 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 made easy for fast time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP, CC2531
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity and blocking performance systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	

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

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

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.

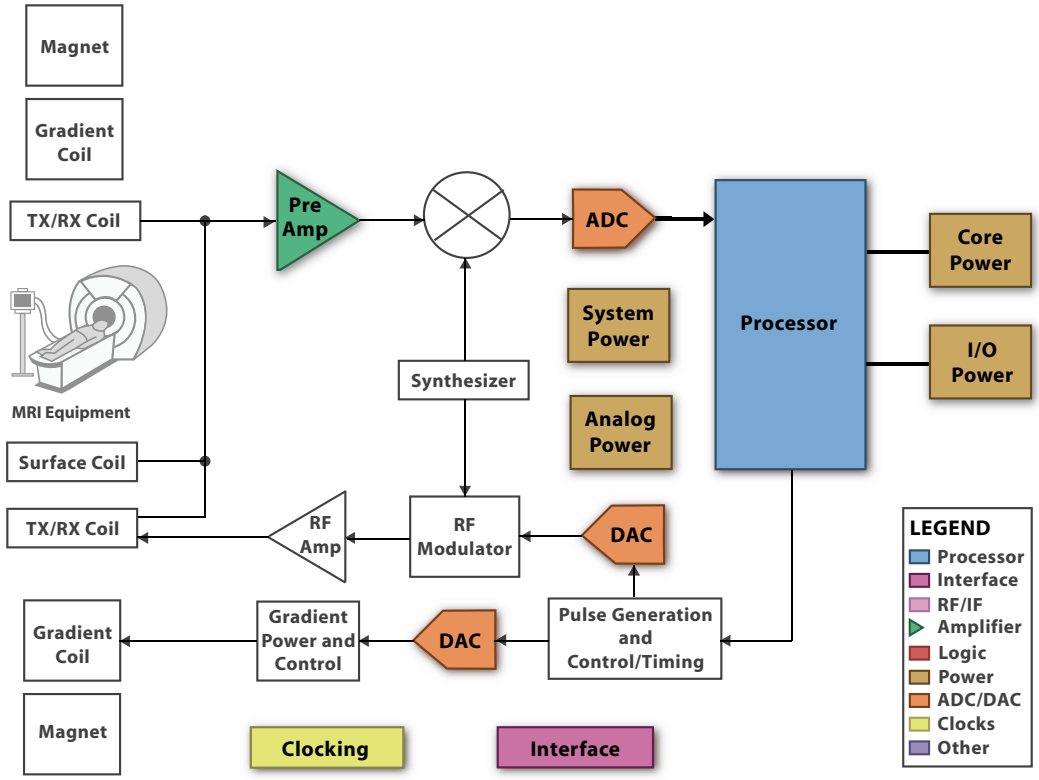
High-resolution, high-speed DACs are needed to control the magnetic and RF energy in the MRI. High resolution is required to accurately define the area of the patient to be scanned and high speed is needed to match the high IFs generated by the main magnet.

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)

16-Bit, 10MSPS Delta-Sigma ADCs for Scientific Instrumentation

ADS1605, ADS1610

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/ADS1605** or **www.ti.com/sc/device/ADS1610**

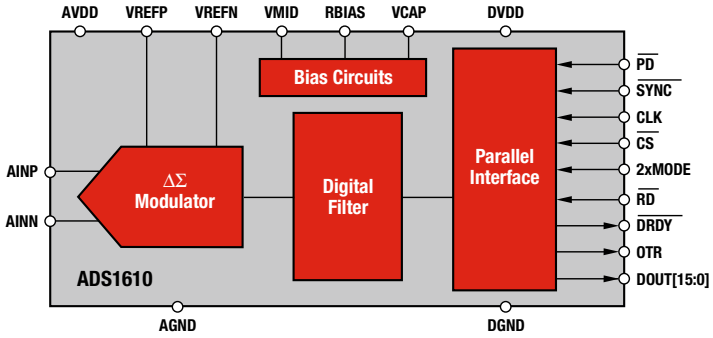
Key Features

- Output data rate: 10MSPS (ADS1610), 5MSPS (ADS1605)
- Signal bandwidth: 4.9MHz
- SNR: 86dBFS
- THD: –94dBS
- SFDR: 95dB
- On-chip digital filter simplifies anti-alias requirements
- Low group delay: 3µs
- Parallel interface
- Direct connection to TMS320 DSPs
- Packaging: TQFP-64

The ADS1610 delta-sigma topology provides key system-level design advantages with respect to anti-aliasing filtering and clock jitter. Output data is supplied over a parallel interface and easily connects to TMS320™ DSPs. The power dissipation can be adjusted with an external resistor, allowing for reduction at lower operating speeds.

Applications

- Scientific instruments
- Test equipment
- Communications



ADS1610 functional block diagram.

12, 14-Bit, Single, Dual and Quad ADCs from 65 to 250MSPS

ADS64xx, ADS62xx, ADS62Pxx, ADS61xx, ADS61Bxx

Get samples, datasheets and evaluation modules at: **www.ti.com/sc/device/ADS6424**

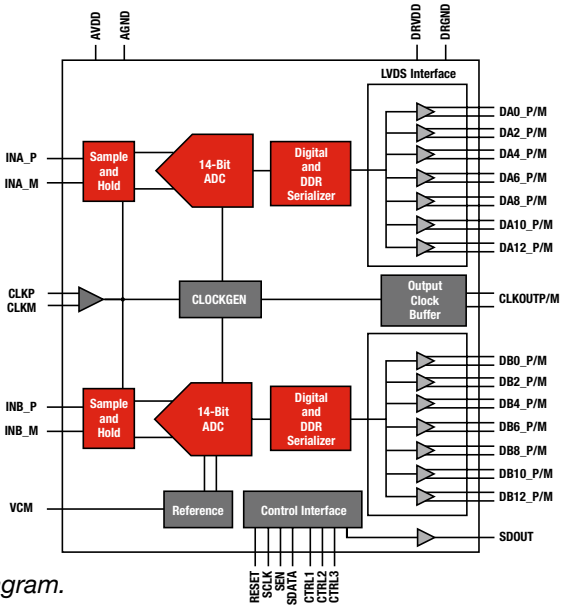
Key Features

- 11, 12, 14-bit res. from 65 to 250MSPS
- Quad, dual and single versions
- Total power: 260 to 780mW per ch.
- SNR: 70dBFS at F_{IN} = 250MHz, 125MSPS
- SFDR: 81dBc at F_{IN} = 250MHz, 125MSPS
- 3.5dB coarse gain, up to 6dB programmable fine gain for SFDR/SNR trade-off
- Serialized (quads, duals) and parallel (duals, singles) output options
- Programmable output terminations and LVDS drive strength
- Analog and digital supply: 3.3V

Applications

- Software defined radios
  - Multi-antenna receivers
  - High IF receivers
- Wireless communications:
  - DPD feedback loops
  - Wideband digital repeaters
- High density general purpose digitizers

The ADS6000 family features high-performance single and dual channel ADC solutions from 65 to 250MSPS and quad ADC solutions from 65 to 125MSPS, with both parallel and serialized output options. The family is designed for demanding wireless applications with high performance at high IFs — up to 70dB SNR with 81dBc SFDR at 250MHz. The ADS6000 family is extremely flexible with programmable gain settings, LVDS termination resistors and LVDS drive strength. Additionally, all family members with the same channel and output format are pin-for-pin compatible, allowing for eased migrations between speeds and resolutions.



Functional block diagram.

Magnetic Resonance Imaging (MRI)

Wideband Operational Transconductance Amplifier

OPA861

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/OPA861**

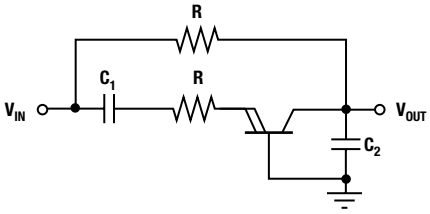
Key Features

- Wide bandwidth: 80MHz, open-loop, G = +5
- High slew rate: 900V/µs
- High transconductance: 95mA/V
- External I_Q control
- Low quiescent current: 5.4mA

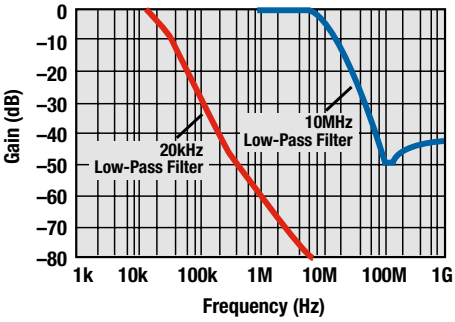
Applications

- Video equipment
- Communications
- High-speed data acquisition
- Wideband LED drivers
- Control-loop amplifiers
- Wideband active filters
- Line drivers

The OPA861 is a wideband, bipolar operational transconductance amplifier (OTA). The OTA or voltage-controlled current source can be viewed as an ideal transistor. Like a transistor, it has three terminals — a high-impedance input (base), a low-impedance input/output (emitter) and the current output (collector). The OPA861, however, is self-biased and bipolar. The output collector current is zero for a zero base-emitter voltage. AC inputs centered about zero produce an output current, which is bipolar and centered about zero. The transconductance of the OPA861 can be adjusted with an external resistor, allowing bandwidth, quiescent current and gain trade-offs to be optimized.



Low-pass negative impedance converter (NIC) filter.



Frequency response of 20kHz and 10MHz low-pass NIC filters.

High-Performance Fixed-Point DSP

TMS320C6452

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320C6452**

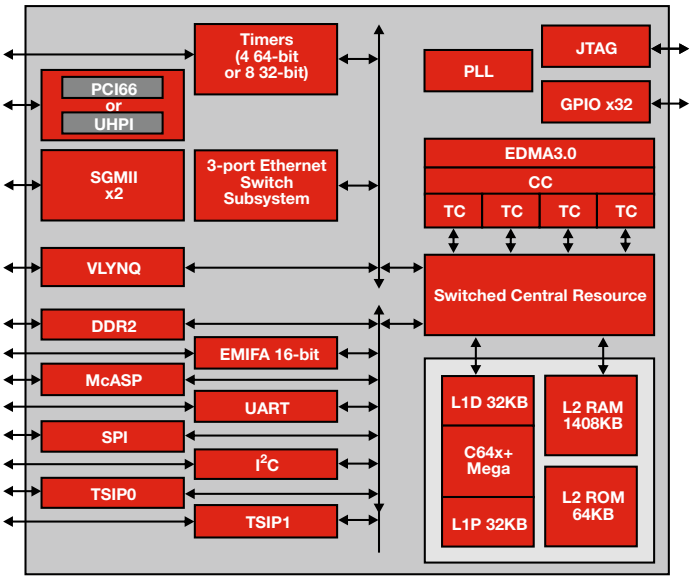
Key Features

- 720, 900MHz C64x+™ clock rate
- 1.39, 1.11ns instruction cycle time
- 5760, 7200MIPS
- Eight 32-bit C64x+ instructions/cycle
- Extensions to VelociTI™ advanced very-long-instruction-word (VLIW) TMS320C64x+™ DSP core
- C64x+ instruction set features
- C64x+ L1/L2 memory architecture

Applications

- MRI
- Imaging
- Telecom infrastructure
- Communications

TMS320C64x+ DSPs are the highest performance fixed-point DSP generation in the TMS320C6000™ DSP platform. The C6452 device is based on the third-generation high-performance, advanced VelociTI very-long-instruction-word (VLIW) architecture, making these DSPs an excellent choice for applications including medical imaging, telecom infrastructure and communications. The C64x+ devices are upward-code-compatible from previous devices that are part of the C6000™ DSP platform.



TMS320C6452 functional block diagram.

Magnetic Resonance Imaging (MRI)

8-Channel, Ultra-Low-Power, 12- and 10-Bit, 50- to 65-MSPS 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

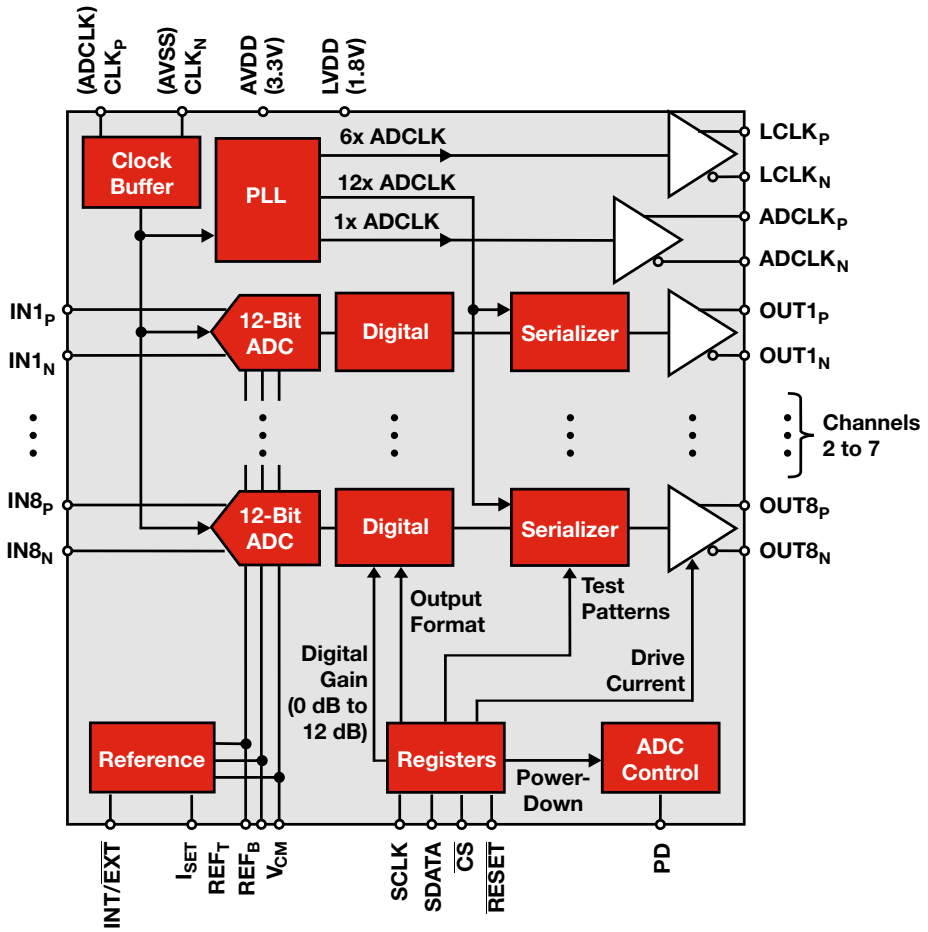
Applications

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 the optimal solution for the entire spectrum of imaging systems.



ADS5281/2/7 functional diagram.

Magnetic Resonance Imaging (MRI)

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
OPA861 *Page 107	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				
ADS1605 *Page 106	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 *Page 106	Delta-Sigma ADC	16-bit, 10MSPS, parallel interface	SYNC pin for simultaneous sampling	ADS1605
ADS5281 *Page 108	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 *Page 108	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 *Page 106	High-Speed ADC	11- /12- /14-bits, 65 to 250MSPS, 3.3V, 260 to 780mW per channel	High performance	ADS62xx, ADS62Pxx, ADS64xx
ADS62xx/62Pxx *Page 106	High-Speed ADC	11- /12- /14-bits, 65 to 250MSPS, 3.3V, 260 to 780mW per channel	High performance	ADS61xx, ADS61Bxx, ADS64xx
ADS64xx *Page 106	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
References				
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

**For additional product information see designated page number.*

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

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

Magnetic Resonance Imaging (MRI)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Processors				
OMAP3530	Applications Processor	ARM® Cortex-A8, C64x+™, graphics accelerator, video accelerators	Laptop-like performance at portable power levels	OMAP3503, OMAP3515, OMAP3525
TMS320C6452/55 **Page 107*	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
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
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
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
Digital Up/Down Converters				
GC5016	Digital Up/Down Converter	Quad, 160MSPS for 4 channels, 115dB SFDR	Many multiplex output options	
GC5018	Digital Down Converter	8-channel, real or complex DDC inputs, 115dB SFDR NCO	Final ACG	
Power Management				
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
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS386000	4-Channel Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808
TPS40020	DC/DC Controller	2.25V to 5.5V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ regulation from main power supply	TPS40042
TPS40075	DC/DC Controller	4.5V to 28V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ regulation from main power supply	TPS40057
TPS54317	DC/DC Converter	3.0V to 6.0V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54610/TPS54910
TPS54350	DC/DC Converter	4.5V to 20V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS6206x	Step-Down Converter	High frequency operation, 2x2 QFN package,power save mode	High efficiency, small solution size	TPS62290
TPS62110	Step-Down Converter	3.1V to 17V V_{IN}, 1.5A conversion, synchronization pin, Low battery indicator, power save mode	Very low noise/high efficiency	TPS62050
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62420
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74301, TPS74801

**For additional product information see designated page number.*

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

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

Magnetic Resonance Imaging (MRI)

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	
UCD90120	12-Channel Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling w/64-B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible w/existing systems; suitable for fast frequency-hopping systems	CC2500
CC2520	2.4GHz ZigBee/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temp range; AES-128 security module	Reliable RF link w/interference; 400m line-of-sight range with dev. kit; ideal for industrial apps; no external processor needed for secure communication	CC2530
RF Systems-on-Chip				
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	USB enabled 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
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's Digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity/blocking performance systems; excellent coexistence w/*Bluetooth*® technology and Wi-Fi.	

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

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

Digital X-Ray

Digital X-rays – made possible because of technologies like digital signal processing – 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.

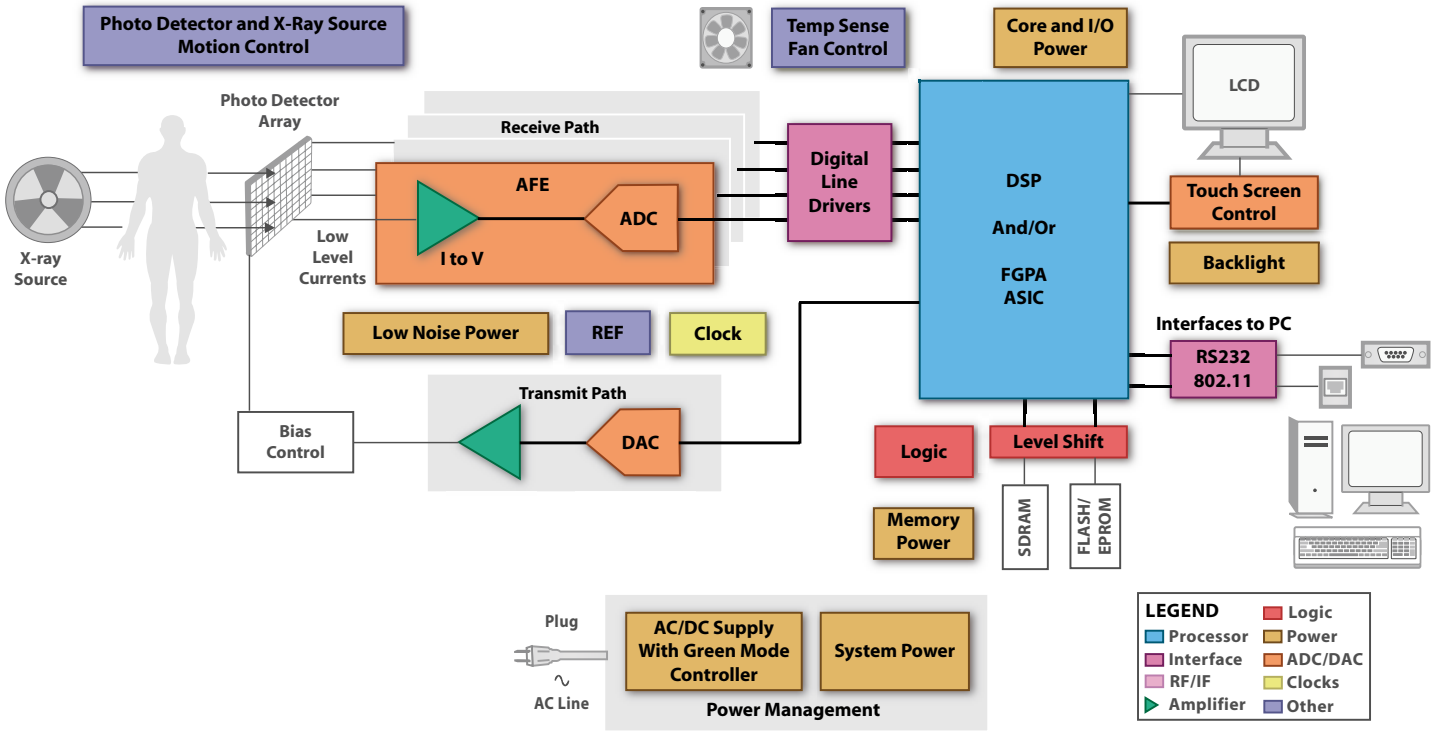
A conventional X-ray system, regardless of whether its individual components are optimized, captures less than 40 percent of the original image information. By adding a digital detector to digital X-ray imaging, it is possible to capture more than 80 percent of the original image information and use 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.



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

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

- High-performance DSPs for control functions and signal conditioning to acquire and improve the clarity of the image.
- 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.
- Temperature sensors, DACs, amplifiers and high-input voltage-capable switching regulators are other key system blocks.
- Power management and other analog products.

Digital X-Ray

16-Bit, 4MSPS, Fully Differential Input ADC with Parallel Interface and Reference

ADS8422

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/ADS8422**

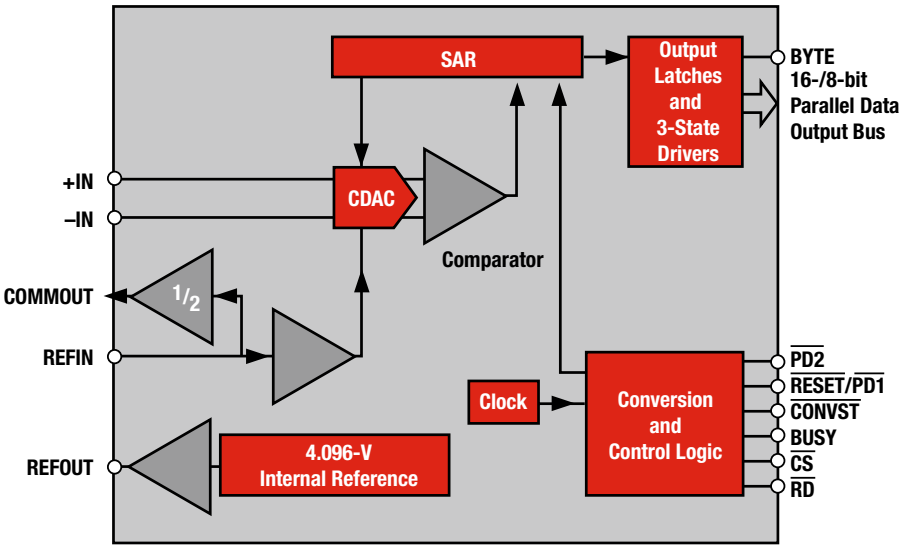
Key Features

- Fully differential input with pseudo-bipolar input range: –4V to +4V
- 16-bit NMC at 4MSPS
- INL: 1LSB (typ)
- SNR: 92dB
- THD: –102dB (typ) with 100kHz input
- Internal 4.096V reference and reference buffer
- High-speed parallel interface
- Low power: 155mW at 4MHz (typ)
- Flexible power-down scheme
- $REF_{IN}/2$ available for setting analog input common-mode voltage

Applications

- Medical instruments
- Instrumentation
- Spectrum analysis
- High-speed, high-resolution, zero-latency data acquisition systems

The ADS8422 is a 16-bit, 4MSPS ADC with internal 4.096V reference and a fully differential, pseudo-bipolar input. It includes a full 16-bit interface and an 8-bit option where data is read using two 8-bit read cycles if necessary. It is characterized over the industrial –40°C to +85°C temperature range.



ADS8422 functional block diagram.

High-Speed, Low-Noise, Fully Differential I/O Amplifiers

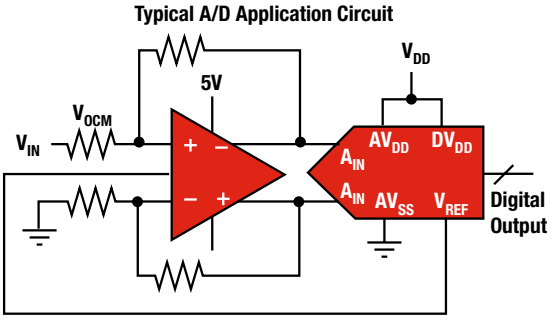
THS4130, THS4131

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/THS4130** or **www.ti.comsc/device/THS4131**

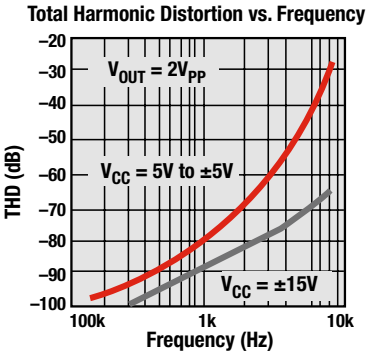
Key Features

- Bandwidth: 150MHz (–3dB, V_{CC} = ±15V)
- Slew rate: 51V/µs
- THD_3 at 250kHz: –100dB
- Low noise: 1.3nV/√Hz input referred noise
- Differential input/differential output:
  - Balanced outputs reject common-mode noise
  - Reduced second harmonic distortion due to differential output
- Wide power supply range:
  - Single supply: V_{CC} = 5V
  - Dual supply: ±15V
- Packaging: SOIC-8, MSOP-8, MSOP-8 PowerPAD™ integrated circuit package

The THS4130 and THS4131 are fully differential input/differential output amplifiers with a true fully differential signal path from input to output. This design provides excellent common-mode noise rejection and improved total harmonic distortion.



THS4130 application circuit.



Applications

- Single-ended to differential conversion
- Differential ADC driver
- Differential antialiasing
- Output level shifter
- Differential transmitter and receiver

Digital X-Ray

Low-Noise, Very Low-Drift, High-Precision Voltage References
REF50xx

Get samples, datasheets and application reports at: **www.ti.com/sc/device/REF5020**

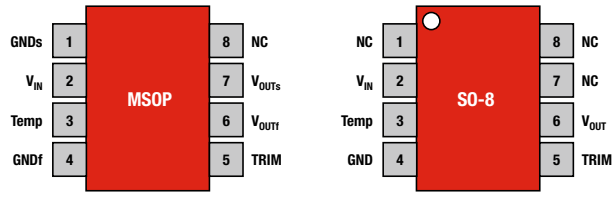
Key Features

- High accuracy: 0.05%
- Very low temperature drift: 3ppm/°C
- High output current: ±10mA
- Temperature range: –40°C to +125°C
- Packaging: MSOP-8, SO-8

Applications

- Medical instruments
- 16-bit data acquisition systems
- Industrial process control
- ATE equipment

The REF50xx is a family of low-noise, low-drift, high-precision voltage references. Designed for use in high-precision data acquisition systems, REF50xx has both sinking and sourcing capability and is very robust to any line and load changes. The REF50xx has excellent temperature drift (3ppm/°C) and high accuracy both, achieved by using a proprietary design technique and post-package precision correction.



Package diagrams.

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

TMS320C28x™ Controller Generation, Fixed-Point MCU Control, DSP Performance
TMS320F2810

Get samples, datasheets, tools and application reports at: **www.ti.com/sc/device/TMS320F2810**

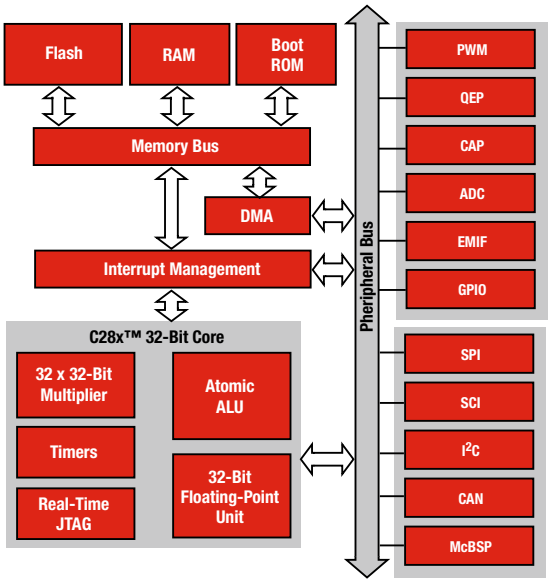
Key Features

- Ultra-fast 20 to 40ns service time to any interrupts
- Powerful 20Mbps data logging debugging capability
- 32-/64-bit saturation, single-cycle read-modify-write instructions, and 64-/32-bit and 32-/32-bit modulus division
- Enhanced tool suites with C and C++ support
- Unique real-time debugging capabilities
- 32-bit single-cycle fixed-point MAC
- Compatible with TMS320C24x™ DSPs and TMS320C2xLP source code

Peripherals

- 16 to 128Kword sectored flash or factory-programmed ROM (with code security)
- 12-bit ADC, as fast as 12.5MSPS throughput with 80ns (min) conversion time
- Flexible QEP, CAP, timers and PWM generation
- High-res mode resolution of 16-bits at 100kHz and over 12-bits at 1.5MHz ePWM frequency

The TMS320F2810, TMS320F2811, TMS320F2812, TMS320C2810, TMS320C2811, and TMS320C2812 ICs, members of the TMS320C28x DSP generation, are highly integrated, high-performance solutions for demanding control applications. The C28x™ controllers are 32-bit control-based DSPs with onboard reprogrammable flash, factory-programmed ROM, or cost-effective RAM-only memory options and performance from 100 to 150MIPS.



TMS320C28x digital signal controller block diagram.

- Up to two serial communication interfaces (SCI/UART)
- Up to four serial peripheral interfaces (SPI)
- Up to two enhanced CAN 2.0B modules
- McBSP or I^2C interface

Digital X-Ray

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Amplifiers				
OPA211	Precision Op Amp	1.1nV/√Hz at 1kHz noise, 3.6mA/ch supply, 80MHz BW	Unity gain stable, RRO, shutdown	OPA227
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
OPA277	Precision Op Amp	10µV offset, ±0.1µV/°C drift, 134dB open-loop gain		OPA4277 (quad)
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, **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/√Hz noise, 100V/µs SR, 90mA output	Low distortion	THS4051, THS4081
THS413x **Page 114*	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 **Page 114*	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	
Power Management				
DCH010505	Galvanic Isolated DC/DC Converters	1W, 3kV isolation, minimal external components	Safety isolation, removal of ground loops, reducing board space	DCH010512, DCH010515
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
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS386000	4-Ch. Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808

**For additional product information see designated page number.*

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

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

Digital X-Ray

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
Power Management (Continued)				
TPS40020	DC/DC Controller	2.25V to 5.5V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ regulation from main power supply	TPS40042
TPS40075	DC/DC Controller	4.5V to 28V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/regulation	TPS40057
TPS54317	DC/DC Converter	3.0V to 6.0V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54610/TPS54910
TPS54350	DC/DC Converter	4.5V to 20V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS6206x	Step-Down Con.	High frequency operation, 2x2 QFN pkg,power save mode	High efficiency, small solution size	TPS62290
TPS62110	DC/DC Converter	3.1 to 17V_{IN}, 1.5A DC/DC w/integrated switch FET, synchronization pin, enable, low battery indicator, PFM mode	Very low noise/high efficiency	
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62420
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74301, TPS74801
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	
UCD90120	12-Ch. Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, 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
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	
TMS320F2810 *Page 115*	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 ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling w/64-B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible w/existing systems; suitable for fast frequency-hopping systems	CC2500
CC2520	2.4GHz ZigBee/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temp range; AES-128 security module	Reliable RF link w/interference; 400m line-of-sight range with dev. kit; ideal for industrial apps; no external processor needed for secure communication	CC2530
RF Systems-on-Chip				
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	USB enabled 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
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's Digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity/blocking performance systems; excellent coexistence w/*Bluetooth*® technology and Wi-Fi.	
References				
REF50xx *Page 115*	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

**For additional product information see designated page number.*

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

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

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.

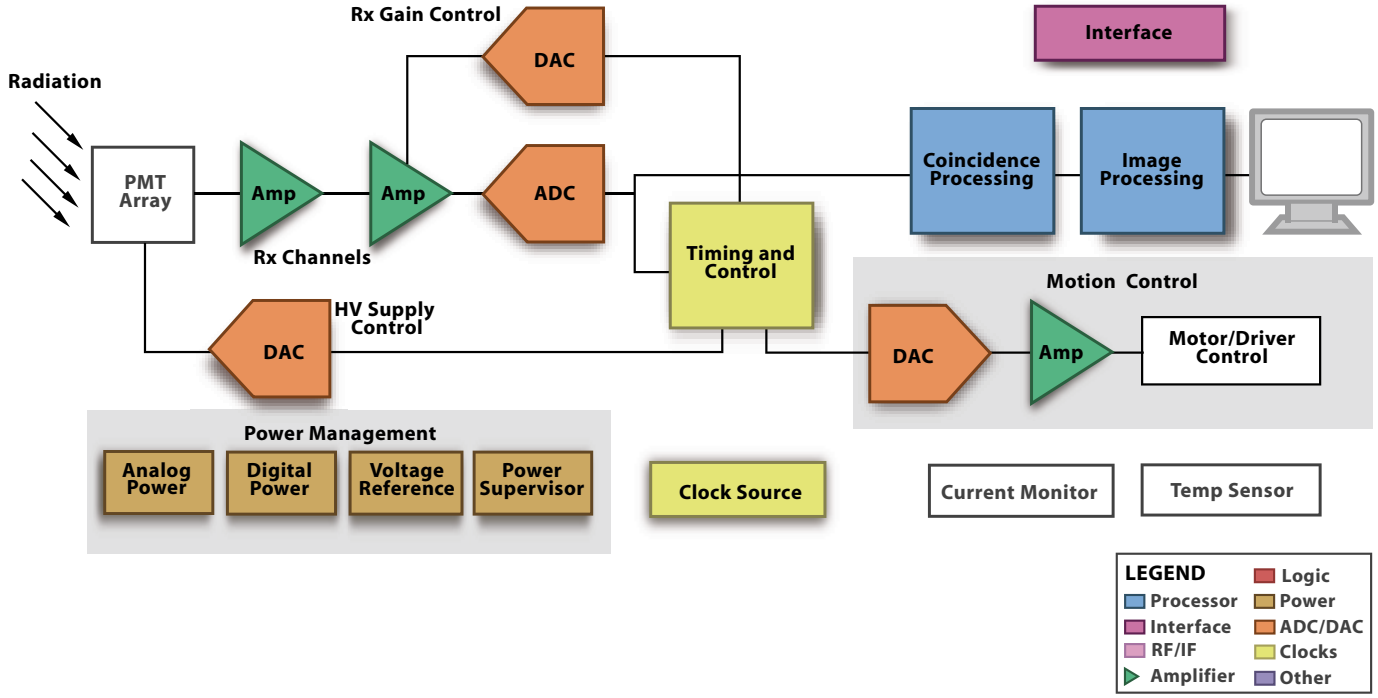
The radioactive emissions are converted to light via a scintillation crystal detector and are amplified and converted to an output current by a photomultiplier tube (PMT). The PMT's current output is then converted to a voltage that is amplified and filtered before being converted to a digital signal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

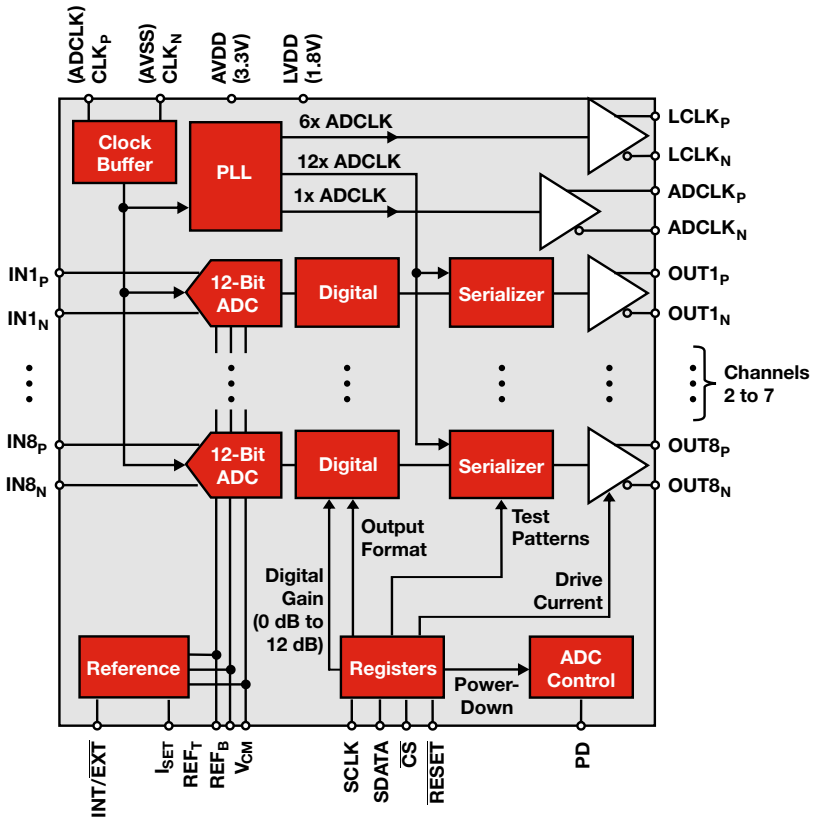
- 8-channel 12- or 10-bit ADCs in one small 64-pin QFN package
  - ADS5281 also available in 80-pin TQFP pin-compatible to ADS527x
- 77mW per channel at 65MSPS; 64mW per channel at 50MSPS
- 70dB SNR for 12-bits at 10MHz IF
- 1/f (flicker) noise suppression
- Up to 6dB overload recovery in one clock cycle
- 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**

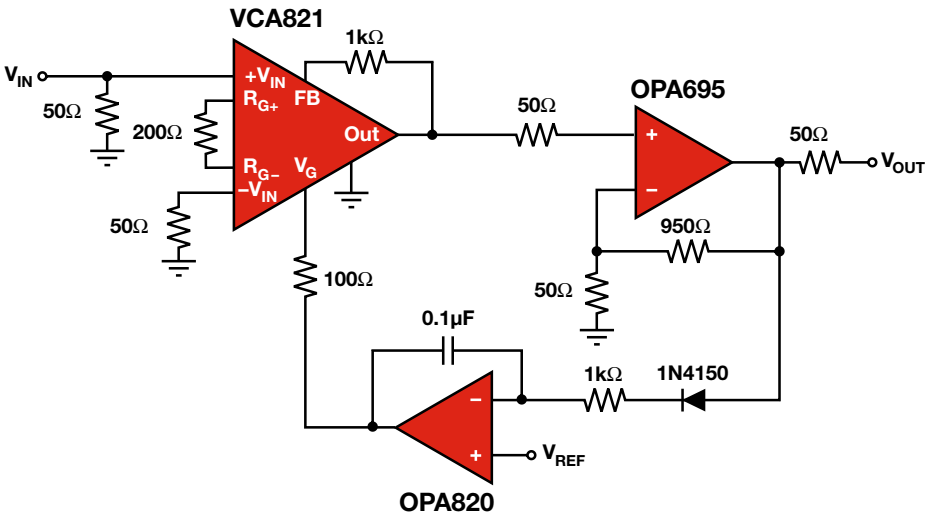
Key Features

- >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				
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 *Page 120	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 *Page 119	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 *Page 119	High-Speed ADC	Ultra-low-power, 8-channel, 12-bit, 65MSPS	77mW per channel, serialized LVDS outputs, 1/f noise suppression	ADS5281, ADS5287
ADS5287 *Page 119	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				
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	

**For additional product information see designated page number.*

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

Positron Emission Tomography (PET) Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
References (continued)				
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
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
Power Management				
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 *Page 125*	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 *Page 125*	Isolated DC/DC Module	100W, 1500VDC isolation, differential remote sense	High efficiency, industry-standard pin-compatible	PTQB425080
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS386000	4-Channel Supervisor	0.25% acc, down to 0.4V, watchdog	High integration and high accuracy	TPS3808
TPS40020	DC/DC Controller	2.25 to 5.5V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/regulation from main power supply	TPS40042
TPS40075	DC/DC Controller	4.5 to 28V_{IN}, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/regulation from main power supply	TPS40057
TPS54317	DC/DC Converter	3.0 to 6.0V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54610/TPS54910
TPS54350	DC/DC Converter	4.5 to 20V_{IN} 3A DC/DC with integrated switch FET, synchronization pin, enable	Eliminate beat noise/ceramic caps/FPGA/ integration	TPS54550
TPS6206x	Step-Down Converter	High frequency operation, 2x2 QFN package,power save mode	High efficiency, small solution size	TPS62290
TPS62110	DC/DC Converter	3.1 to 17V_{IN}, 1.5A DC/DC with integrated switch FET, synchronization pin, enable, Low battery indicator, PFM mode	Very low noise/high efficiency	
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62420
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74301, TPS74801
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	
UCD90120	12-Channel Sequencer	GUI for programming 12 power rails	Sequencing, monitoring and margining	UCD9081, UCD90124

**For additional product information see designated page number.*

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

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

Positron Emission Tomography (PET) Scanners

Component Recommendations (Continued)

Component	Description	Key Features	Benefits	Other TI Solutions
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	
RF ICs				
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling w/64-B data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible w/existing systems; suitable for fast frequency-hopping systems	CC2500
CC2520	2.4GHz ZigBee/ IEEE 802.15.4 RF Transceiver	Best-in-class coexistence and selectivity properties; excellent link budget (103dBm); extended temp range; AES-128 security module	Reliable RF link w/interference; 400m line-of-sight range with dev. kit; ideal for industrial apps; no external processor needed for secure communication	CC2530
RF Systems-on-Chip				
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2530/31	USB enabled 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
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's Digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity/blocking performance systems; excellent coexistence w/*Bluetooth*® technology and Wi-Fi.	

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

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

Power Management for Medical Imaging

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**

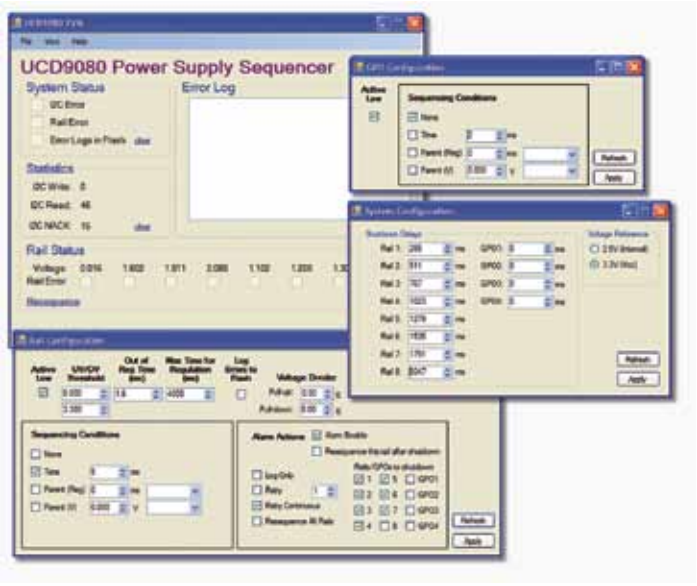
Key Features

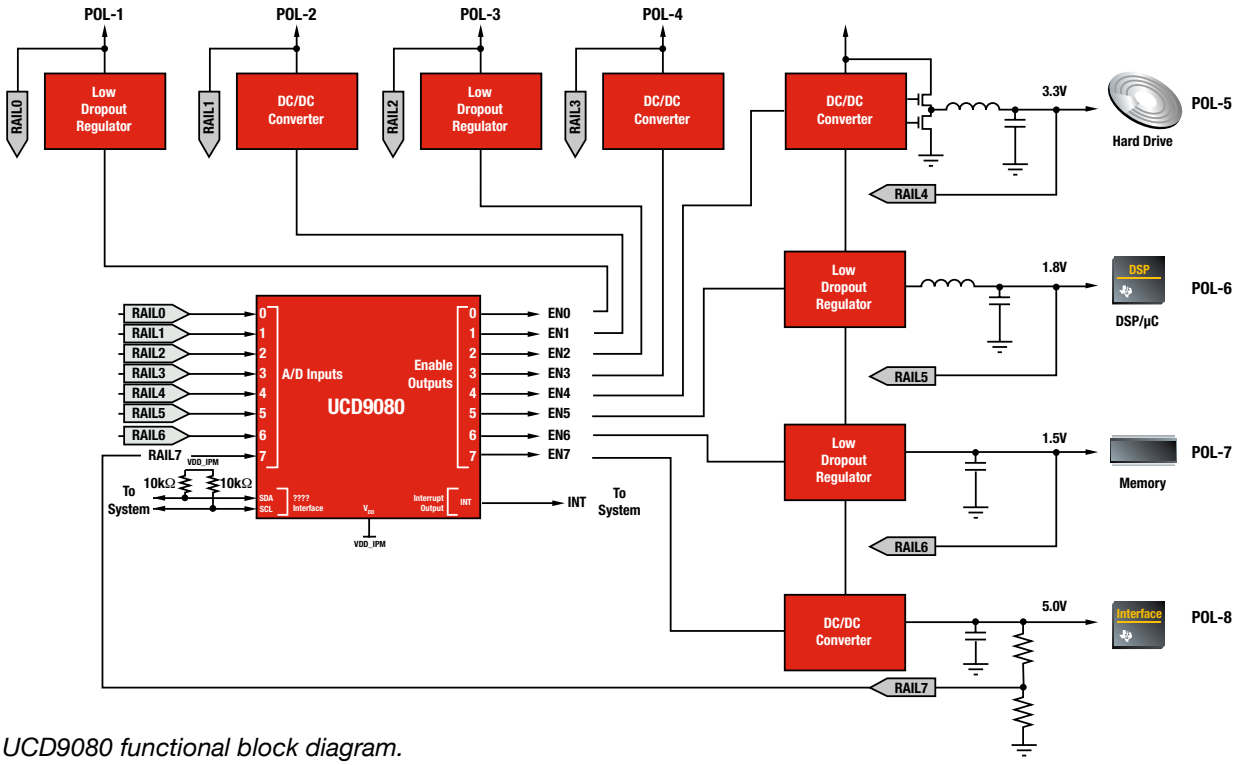
- Sequencing and monitoring of up to eight voltage rails
- All rails monitored and updated every 50µs 3.5mV resolution
- Sequencing of up to three digital outputs for power-on-reset and other functions
- Under- and overvoltage threshold per rail
- I^2C interface for configuration and monitoring
- Microsoft 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 for Medical Imaging

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

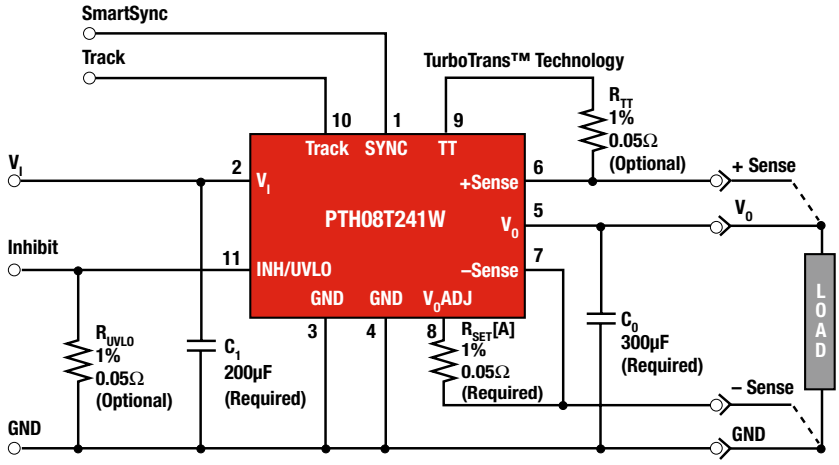
Benefits

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

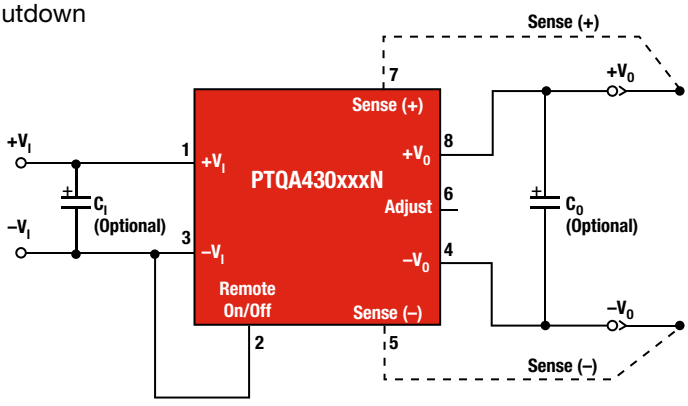
- 48V input (36V to 75V range)
- Standard quarter-brick footprint
- High efficiency (92 percent at 3.3V full load)
- 1500V DC I/O isolation
- On/off control
- Overcurrent protection
- Differential remote sense
- Undervoltage lockout
- Output overvoltage protection
- Overtemperature shutdown

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.

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)

Medical Instruments

Overview

Medical instruments are used in a wide range of caregiver laboratory and clinical applications. Some typical applications include:

- Analytical instrumentation, ultrasonic devices, spectrophotometers,
- Endoscopes and smart pills,
- Surgical instrumentation, surgical power tools, robots and cameras,
- Laboratory instruments, in-vitro diagnostic equipment (for outside-the-body analysis), blood gas analysis, labs on a chip, flow cytometry, microfluidic analysis,
- Robotics prosthetics,
- Therapeutics/hospital beds and power wheel chairs,
- Dental equipment, GaAlAs lasers, ultrasonic scalers, autoclaves.

These applications are very specific in design, consuming a wide variety of sensor, actuation or receiving mechanisms. Most medical instruments share general common system blocks and needs. Examples include the need for high-precision circuits to support the precise acquisition of pressure, light and temperature values and the need to leverage ultra-low-power processing to conserve battery life. This includes the acquisition of small capacitance, changes in capacitance and currents, or changes in voltages or impedances.

TI's portfolio provides several integrated circuit (IC) solutions for these applications. Our precision linear portfolio meets the need for typical ICs by offering low-bias amplifiers (both precision and high-speed) with J-FET inputs, zero-drift operational amplifiers for precision-over-lifetime applications and low-noise amplifiers for sensitive measurement circuits.

Our data acquisition portfolio complements these components by offering high-resolution, low-noise, analog-to-digital and digital-to-analog data acquisition systems. TI's ultra-low-power MSP430 microcontroller family, or a member of one of these three DSP families — TMS320F28x, TMS320DM64x and TMS320C64x™ — can easily manage signal processing tasks. TI's wired and wireless interface integrated circuit products can facilitate a variety of data transmission tasks.

For more information on TI's offering for Medical Instruments, please visit *www.ti.com/medicalinstruments*

Ultrasonics

Ultrasonic technology is not often thought of when leveraging ultra-high-performance analog and embedded processing technology. Today, ultrasonic devices are commonly used for cell disruption and homogenization for a broad range of liquid processing applications, such as:

- Emulsification
- Reaction acceleration
- Dispersion
- Fine mixing
- Degassing

Ultrasonic technology is typically used for therapy, dermally administered drugs and skin/wound therapy. Ultrasonic waves are generated at a frequency above 20 kHz to avoid audible detection and are propagated in a gaseous liquid or solid medium. One benefit of utilizing ultrasonic waves is the esoteric directional nature of this technology, which can be focused onto the density and elasticity of the medium of interest.

Piezoelectric transducers are commonly used to convert electrical oscillations to corresponding mechanical vibrations, resulting in intense agitation of the medium of choice. This intense disturbance causes millions of microscopic cavities or voids to form and collapse, which is known as cavitation. When the cavities collapse or implode, they release energy and produce the desired effect.

Endoscopes

In medicine, an endoscope is used to look inside the body to examine the interior of a body cavity or hollow organ such as gastrointestinal, respiratory and urinary tracts. A rigid or flexible endoscope tube is inserted into the body through a natural body orifices or small incision to provide images of the organs.

Surgical instruments are often incorporated into the endoscope to enable minimally invasive procedures such as biopsies and removal of polyps. Some common procedures include colonoscopy, gastroscopy, angioscopy and bronchoscopy.

The primary components of an endoscope include a light source, a tube to guide the light, a lens or fiber optic system to capture reflected light of the organ and an image capture system to process, display and store images. For more information, refer to endoscope section on page 139.

Smart Pills

First introduced in 1992, a smart pill refers to any pill that delivers or controls the delivery of medicine without patient intervention beyond consuming the device.

The most common application is controlled drug delivery within the gastrointestinal tract. Other applications include monitoring or electronic stimulation of the gastrointestinal tract to achieve the desired result, combined with a controlled pharmaceutical delivery. Variables such as time, temperature, pressure, pH and/or location within the intestinal tract are monitored and measured.

Overview

Common smart-pill system components include analog signal conversion, data processing, an RF transceiver (ISM band or other) and the conversion of digital signals for actuator control. A patient can wear a data receiver, and the receiver will provide data that can be downloaded at a later time. The data receiver commonly comprises an RF transceiver, potential data processing and memory for data storage.

Surgical Robotics

Sophisticated surgical robots now enable complex surgery using minimally invasive approaches. These systems consist of a surgical control system leveraging pressure, acceleration and angular rate sensors interfaced to high-performance amplifiers and data converters on the front end, then coupled to embedded processors communicating with robotic arms containing several degrees of motion and low-voltage DC motors. Some systems can also include a high-definition or stereoscopic 3-D display/vision system. These systems filter and translate the surgeon's hand movements into minute and precise movements of the robotic arms and attached medical instruments.

Robotic Prosthetics

Robotic prosthetics are being adapted to work with various control systems. The electrical system required is much like a surgical robot, with the exception that one such approach being tested today includes an interface to myoelectric switches, which are wired to residual nerves and muscles in the upper body and respond to movement impulses from the brain. Robotic prosthetics are now being controlled by thought.

In addition, by combining carbon nanotubes with a specially designed polymer, researchers are making a material that looks, feels and functions like human skin. This synthetic skin could lead to next-generation prosthetic arms with which patients could experience the sense of feel, shake hands and more easily perform ordinary tasks.

Flow Cytometry

Flow cytometry is the measurement ("meter") of single-cell ("cyto") characteristics suspended in a flowing saline stream. A focused beam of laser light illuminates each moving cell and light is scattered in all directions. Detectors placed in front or to the side of the laser beam's intersection point receive pulses of scattered light and convert them into a form suitable for computer analysis and interpretation. The total amount of detected forward-scattered light depends on cell size and refractive index, but is closely correlated with the cross-sectional area of the cell as seen by the laser. The amount of side-scattered light can indicate nuclear shape or cellular granularity.

The improved signal-chain concept shown below supports the dynamic range, speed and linearity required to transfer the signal stream from the photodiodes to the processor. The differential signal transmissions over twisted-pair lines provide common-mode noise rejection and therefore a significant improvement in signal quality. Better signal quality ensures more accurate measurements and more reliable statistical analysis.

The most important feature of flow cytometric analysis is that large numbers of particles (100,000 or more) are analyzed one after the other, typically in about one minute. The detection limit is as low as 100 fluorescent molecules per cell. Submicron particles, such as small bacteria and picoplankton, are well resolved.

In contrast to microscopic analysis, which is based on a very limited number of cells seen on a slide (1 to 100), a flow cytometer provides useful information about a broad range of cells and their functions. Fluorescence analysis makes it possible to quantify fluorescence from single cells up to millions of cells after a single sample run from one test tube. Statistical data (like the mean fluorescent intensity and its shifts in time or dependence on cell function) has proven very reliable.

Key features of flow cytometry include:

- Minimal analog errors
- Miniaturization
- Increased analysis speed for pulse throughput
- Increased flexibility for pulse-shape analysis
- Eventual power reduction for battery-operated equipment

DLP® Technology

DLP® Discovery™ 4100

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

Key Features

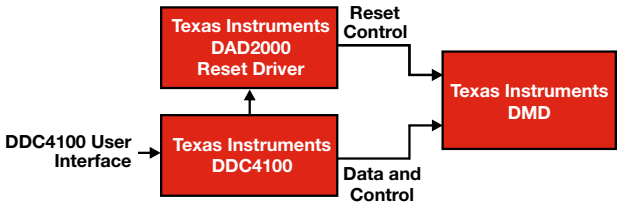
- ±12° mirror operation
- Fill factor > 91percent
- Works with visible, near-infrared and ultraviolet light
- DMD: Options include 0.95" 1080p, 0.7" XGA, 0.55" XGA 2xLVDS
- DAD2000 power and reset driver
  - Generates reset control of 16 banks of DLP mirrors
- DDC4100 digital controller
  - Provides high-speed (400MHz) LVDS data and control interface and provides mirror reset and timing information to the DAD2000
  - Supports random row addressing

Applications

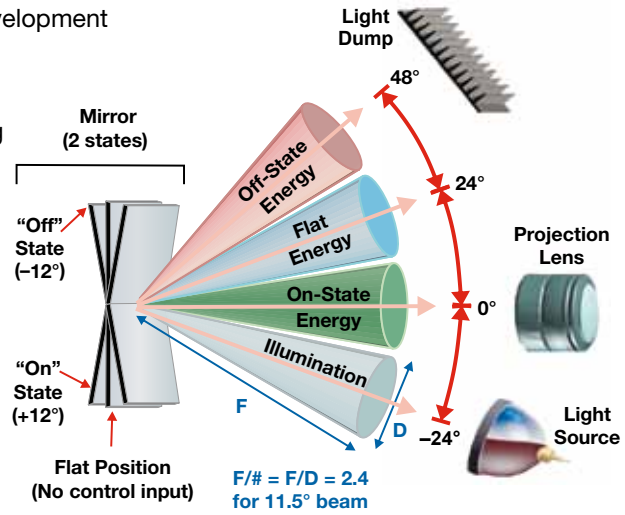
- Vascular imaging
- Phototherapy
- Chemical analysis
- Micro-array development
- 3-D metrology
- Genomics
- Surgical lighting

The D4100 Kit offers developers high performance and high resolution with the 0.95" 1920 x 1080p 2xLVDS DLP chip, an optical semiconductor module that allows developers to manipulate light digitally. When integrated with a light source and optics, this unique device creates binary light patterns with speed, precision and efficiency surpassing that of other spatial light modulators. The D4100 Kit provides performance improvements including increased data rate, frame rate and flexible, random row addressing. The D4100 also supports the 0.55" diagonal and 0.7" XGA 2xLVDS chipsets.

The DLP Discovery 4100 chipset features the DLP chip and other supporting components. Unlike TI DLP controllers optimized for projection display, the D4100 is designed to support a wide variety of DLP-based applications by delivering maximum flexibility in formatting and sequencing data light patterns.



DLP Discovery 4100 chipset block diagram.



How the light is steered.

DLP Discovery 4100 starter kit.

DLP Discovery 4100			
DMD (Digital Micromirror Device)	0.55-inch XGA	0.7-inch XGA	0.95-inch 1080p
Array	1024 x 768	1024 x 768	1920 x 1080
Mirror Pitch	10.8µm	13.68µm	10.8µm
Window Options (Visible, Ultraviolet, Near Infrared)	VIS	VIS, UV, NIR	VIS, UV
Clock Rate (Maximum)	400MHz (2 x LVDS)	400MHz (2 x LVDS)	400MHz (2 x LVDS)
Data Rate	25.6GbPs	25.6GbPs	48GbPs
Binary Frames Per Second (Maximum)	32,552	32,552	23,148

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

DLP® Technology

DLP® Pico™ Projector Development Kit v2

DLP1PICOKIT

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

Key Features

- Very small form factor, 44.8 x 67.4 x 14.2mm^3
- Direct connection to a PC, via a HDMI or DVI port
- Selectable DMD pattern rates, up to 2400Hz
- Sync signal output
- Auxiliary connector, for direct access to I^{2}C bus

Applications

- Portable display devices
- 3-D optical measurement
- Augmented reality
- Embedded display devices
- Microscopy
- Medical imaging

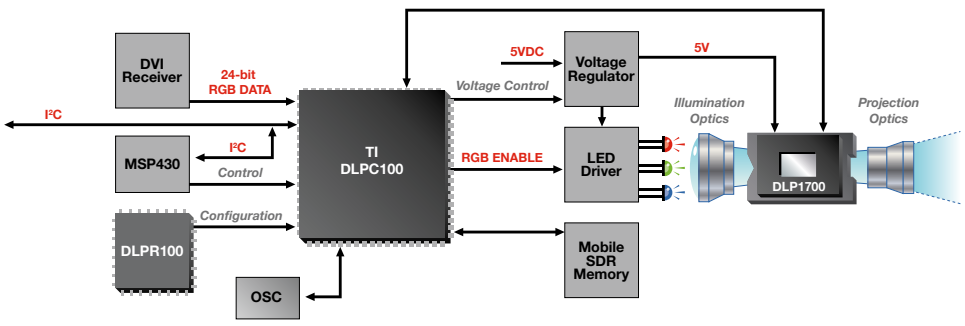
The DLP Pico Projector Development Kit v2 enables developers to integrate DLP Technology into innovative and portable applications. The projection device utilizes the DLP 0.17-inch HVGA chipset with a light engine containing three solid-state color LEDs as a low-power light source. The kit includes a power supply, video cable and HDMI-to-DVI adapter. The DLP Pico Projector Development Kit is a fully integrated projection solution that enables a vast array of new and portable medical devices.

Pico Projector Specifications	
DMD Resolution	0.17-inch HVGA
Brightness	Up to 10 lumens
Contrast ratio	1000:1
Light source	Solid-state 3 LED
Video input	DVI-D 888RGB VGA 50 and 60Hz
Dimensions	44.8 x 67.4 x 14.2mm^3

DLP Pico Projector Development Kit.

DLP 0.17 HVGA Chipset

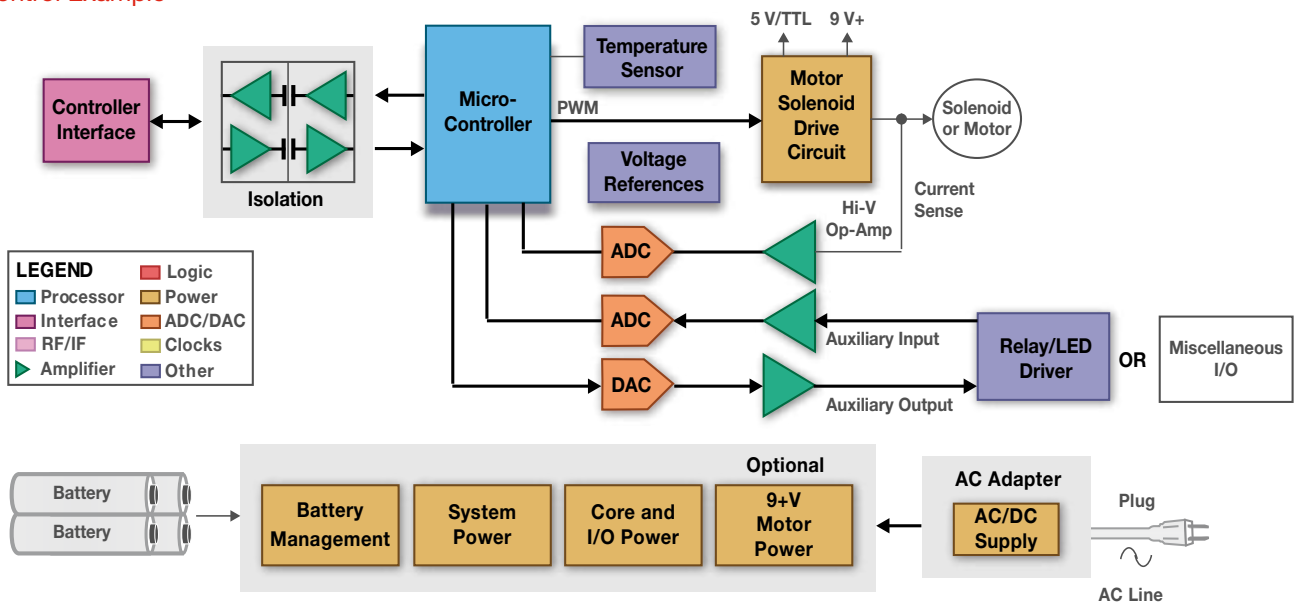
GPN	Description	Functions	Benefits
DLP1700	(DMD) Digital Micromirror Device	MEMS component containing an array of aluminum micromirrors, atop a CMOS substrate, that digitally switch in a binary state	Fast and reliable spatial light modulator to enable light processing and embedded display applications
DLPC100	DMD Digital Controller	Conveniently interfaces user electronics to the DMD	Provides developers the flexibility to control the mirrors independently and at high speeds
DLPR100	Controller Configuration PROM	Contains the DMD digital controller program data	Enables more advanced spatial light modulation than found in traditional projection systems



Block diagram of projection system using 0.17 HVGA chipset.

Design Considerations

Motor Control Example



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 Stellaris® ARM® Cortex M3 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.

Note: "Motor Control Guide" (slyy017)
www-s.ti.com/sc/techlit/slyy017

Design Considerations

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.

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.

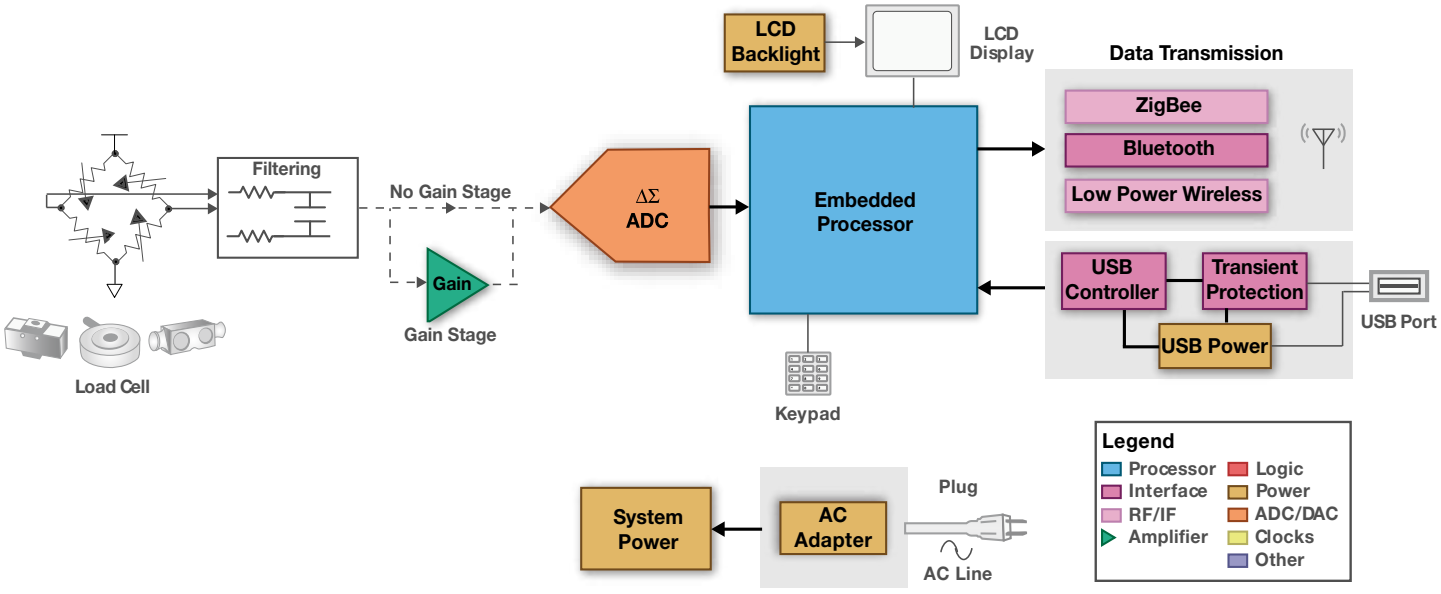
See the application note at *www.ti.com/comparingbussolutions* for additional information on interface selection.

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.

Sensor Signal Chain

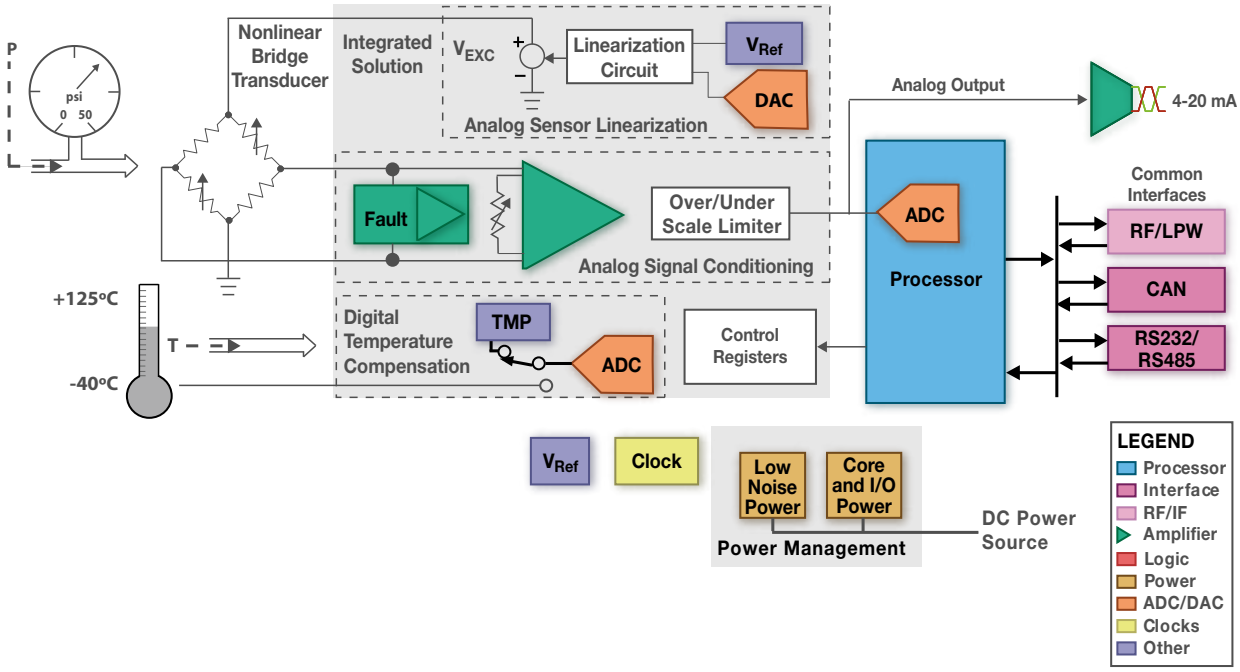
Weigh Scale Sensor Example



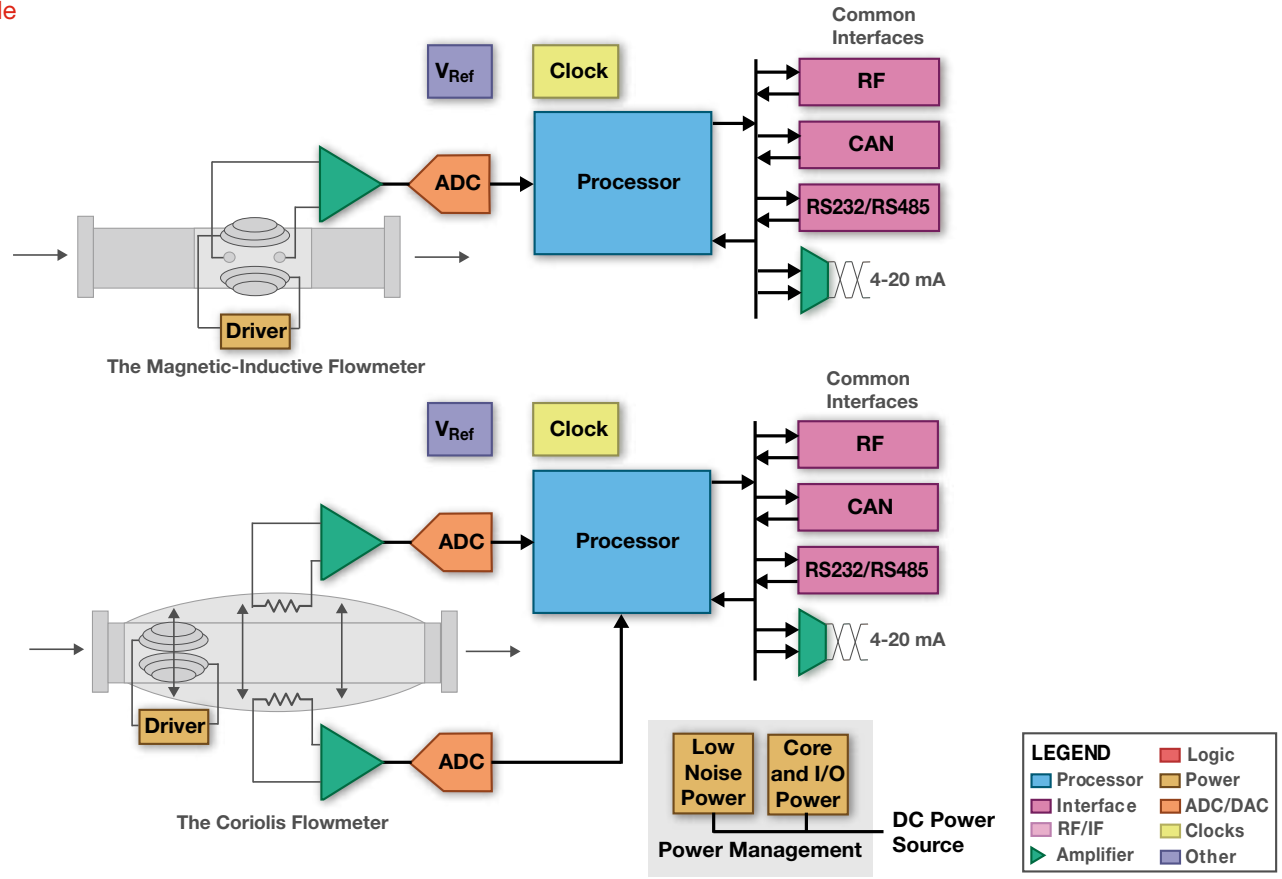
Design Considerations

Sensor Signal Chains

Pressure Sensor Signal Chain Example



Flow Meter Sensor Signal Chain Example



Design Considerations

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 $G = 1 + (100k\Omega/RG)$.

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 multichannel 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.

Design Considerations

The challenges in implementing this ease of use is strikingly similar to cellular phone systems. TI's OMAP technology with embedded ARM® and DSP processor cores directly addresses these challenges. 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.

C5000™ Processors

TI's TMS320VC5504/05/14/15 DSPs offer the industry's lowest standby power consumption (<150µW) and the industry's lowest active power consumption (0.15mW/MHz). These two new pin-to-pin compatible processors maximize energy efficiency, extending battery life for portable devices while reducing system cost and enabling user-friendly features. While successful in the portable monitoring space, these devices also find themselves well positioned for the medical instrumentation segment, providing high integration of peripherals such as a 1024-point programmable fast Fourier transform (FFT) hardware accelerator, a high speed USB 2.0 with physical layer (PHY), LCD display controller, and a MultiMedia Card/Secure Digital (MMC/SD) and 10-bit, four-channel successive approximation register (SAR) analog-to-digital converter.

The Stellaris® MCU Family of Processors (Luminary)

Medical instrumentation requires accuracy, reliability and responsiveness. Whether connected or standalone, Stellaris 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.

Stellaris MCUs and ARM Cortex-M3 offer a direct path to the strongest ecosystem of development tools, software and knowledge in the industry. Designers who migrate to Stellaris will benefit from great tools, small code footprints and outstanding performance.

The Stellaris family offers the industry's first and broadest implementation of Cortex-M3 and the Thumb-2 instruction set. With blazingly fast responsiveness, Thumb-2 technology combines both 16- and 32-bit instructions to deliver the best balance of code density and performance. Thumb-2 uses 26 percent less memory than pure 32-bit code to reduce system cost while delivering 25 percent better performance.

Newly acquired into TI's expansive microcontroller portfolio, Stellaris 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 Stellaris 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 or TMS320C55x DSP 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.

Component Recommendations

Amplifiers

Component	Description	Key Features	Benefits	Other TI Solutions
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/√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/√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 .04 mm 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
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
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

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

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

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
Data Converters (Continued)				
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
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	
Power Products				
REF3130	SOT23-3 Series Voltage Reference	15ppm/°C, 0.2% accuracy at 25°C	Low power consumption, low dropout.	REF3112, REF3120, REF3125, REF3133
TPS3307	Voltage Supervisor	Triple processor supervisor	Two fixed and one adjustable supervisor for system flexibility	TPS3808
TPS61081	LED Boost Converter	Input-to-output isolation	Protection from short between any pins and between any pin to ground	TPS61042
TPS61093	OLED Boost Converter	Wide V_{IN} range, input-output disconnect	Flexible, fail safe solution	TPS61080
TPS62110	Step-Down Converter	3.1V to 17V V_{IN}, 1.5A conversion, synchronization pin, Low battery indicator, power save mode	Very low noise/high efficiency	TPS62050
TPS62400	Dual Output Step-Down Converter	180° out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410
TPS62750	Step-Down Converter	Programmable input current limit, hot plug and reverse current protection	Supports USB powerde applications and large.output caps	TPS62040
TPS63000	Buck-Boost Converter	1.8A switch, automatic transition between step down and boost mode	Stable output voltage over entire entire V_{IN} range	TPS63010
TPS63030	Buck-Boost Converter	1A switch, automatic transition between step down and boost mode	Extending Application run time, Small Solution	TPS61020
TPS717xx	Single-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS799xx
TPS718xx-yy	Dual-Channel LDO	Very high rejection of power-source noise	Low-noise power rails for sensitive analog components	TPS719xx-yy
TPS74201	Single-Channel LDO	1.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74301, TPS74801
TPS74401	Single-Channel LDO	3.0A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74901
TPS74701	Single-Channel LDO	0.5A ultra-low-dropout linear regulator	Split bias and supply pin minimize heat generation	
TPS79901	Single-Channel LDO	Very high rejection of power source noise	Low-noise power rails for sensitive analog components	TPS79501
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

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

Component Recommendations

Component	Description	Key Features	Benefits	Other TI Solutions
RF Transceivers				
CC1101	Sub-1GHz RF Transceiver	Wake-on-radio functionality; integrated packet handling with 64-byte data FIFOs; high RF flexibility: FSK, MSK, OOK, 1.2-500Kbps; extremely fast PLL turn-on/hop time	Ideal for low-power systems; any low-end MCU can be used; backwards-compatible with existing systems; suitable for fast frequency-hopping systems	CC2500
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; 400-m line-of-sight range with the development kit; ideal for industrial applications; no external processor needed for secure communication	CC2530
RF System-on-Chip				
CC2560	2.4GHz *Bluetooth*® 2.1 chipset	Single-chip *Bluetooth*® solution using TI's digital radio processor technology.	Sophisticated low-power technology ideal for battery operated solutions	
CC1110/11	Sub-1GHz System-on-Chip	MCU, USB 2.0, flash and RAM in one package; four flexible power modes for reduced power consumption; includes CC1101 transceiver frequency synthesizer; built-in AES-128 encryption coprocessor	Complete low-cost solution on single chip; ideal for low-power, battery-operated systems; robust and secure link with good noise immunity; no external processor needed for secure communication; can connect directly to a PC	CC2510, CC2511
CC2431	System-on-Chip Solution for ZigBee® location engine	CC2431 has 32/64/128 KB hardware AES encryption engine, excellent selectivity, blocking performance and hardware location	Ideal for battery operated systems; suitable for proprietary and ZigBee systems; adds location awareness and accuracy of 3 to 5 meters	
CC2530/31	Second Generation 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 SOC for quick time to market; provides a robust and complete ZigBee USB dongle or firmware-upgradable network node	CC2590/91, CC2530ZNP
CC2540	2.4GHz *Bluetooth*® Low Energy compliant RF System-on-Chip	Excellent link budget enabling long range applications without external frontend, receiver sensitivity, selectivity and blocking performance	A fast-to-market *Bluetooth*® low energy compliant solution	
WL1271	2.4GHz 802.11b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1273
WL1273	2.4/5GHz 802.11a/b/g/n and *Bluetooth*® 2.1 Chipset	Single-chip 802.11a/b/g/n WLAN and *Bluetooth*® solution using TI's digital radio processor technology using a single antenna.	Sophisticated low-power technology ideal for battery operated solutions; coexistence features enable simultaneous WLAN and *Bluetooth*® operations; supports ANT+ standard.	WL1271
RF Network Processor				
CC2530ZNP	Second Generation Z-Stack™ Network Processor	ZigBee® stack and radio in one chip; implements ZigBee certified stack; configurable device type and network settings	Add CC2530ZNP and your system is ZigBee enabled; ideal for battery-operated excellent selectivity and blocking performance systems; excellent coexistence with *Bluetooth*® technology and Wi-Fi.	
Processors				
AM3517	Applications Processor	ARM® Cortex-A8, graphics accelerators, Ethernet, CAN	High performance at handheld power levels	AM3505
LM3S800	Stellaris® Microcontroller	ARM® Cortex M3 core, 50MHz, 64kB single-cycle flash	Hardware-division and single-cycle multiplication, 21 interrupt channels	LM3S600
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	
OMAP3530	Digital Signal Processor	Low power 64x + ARM® Cortex-A8 CPU, 3440 MMACS, 720MHz	PowerVR SGX graphics accelerator, HD resolution output	OMAP3525, OMAP3515, OMAP3503
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.	
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)	
TMS320VC5505	Digital Signal Processor	High-performance, low-power TMS320C55X DSP generation CPU core	GPIO, 10-bit SAR ADC and I/O for displays	TMS320VC5504
Toolkits				
DLP® Discovery™ 4100 **Page 129*	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® Pico™ Kit **Page 130*	Fully integrates projection solutions for portable medical devices	44.8x67.4x14.2mm^3, I^{2}C command interface	Well suited for incorporating digital projection into portable devices	DLP® Discovery™

**For additional product information see designated page number.*

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

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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.

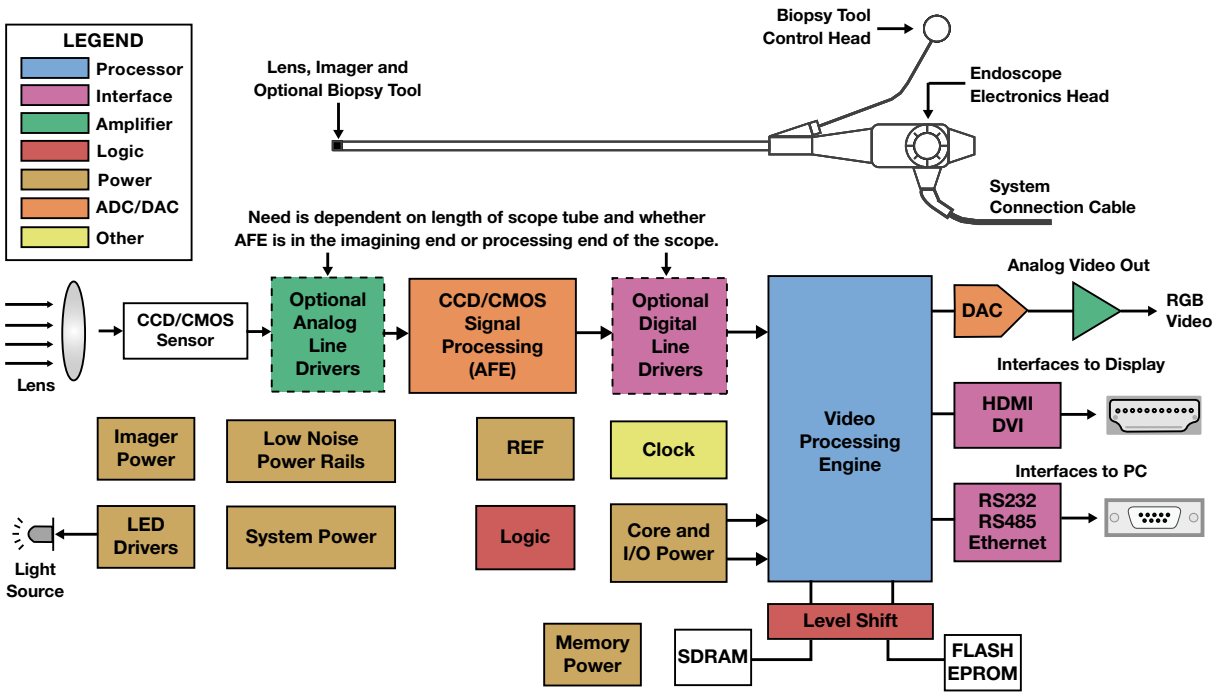
Endoscopes and borescopes have four basic requirements:

- 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.



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

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	
Processors				
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	
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	
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	
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	
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		
Amplifiers				
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 with disable	Designed to work with video processors	OPA3832
OPA830	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
Interface				
SN65LV1023A	10-bit LVDS Serdes	10MHz-66MHz; QFN and TSSOP	Available in 70% smaller QFN package	SN65LV1224B
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
Power Management				
TPS65073	PMU w/charger/WLED	Integrates charger, WLED, DCDC and LDO.	Highest integration for portable applications	TPS65720
TPS61160	White LED Driver	White LED driver with digital and PWM brightness control in 2mm x 2mm package	Allows stepped brightness adjustment	TPS61061
TPS61220	Boost Converter	Down to 0.7V V_{IN} operation, pass-through function	Simple, small, low power solution	TPS61070
TPS62230	Step-Down Converter	Up to 90dB PSRR, excellent AC and transient load regulation	Low noise regulation, 12mm^2 solution size	TPS62260
TPS62400	Dual Output Step-Down Converter	180 degrees out of phase operation, serial interface	Flexible voltage adjustment for processors and MCUs	TPS62410, TPS62111, TPS62260, TPS62290
TPS63030	Buck-Boost Converter	1A switch, automatic transition between step down and boost mode	Extending application run time, small solution	TPS61020
TPS71701	LDO	Low-noise, high-bandwidth-PSRR, low-dropout 150mA linear regulator	Filters out wider range of incoming noise with the high PSRR	TPS718xx family
TPS74201	Single Channel LDO	1.5A ultra low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS74401
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	1.5A ultra low-dropout linear regulator	Split bias and supply pin minimize heat generation	TPS71718, TPS74801
TPS75003	Linear Charge Management	Integrated triple-supply power management IC for Xilinx Spartan FPGAs	Provides all three rails in one package	

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

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

Overview

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. Some of these technologies include 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 consumers and caregivers are requiring data to move from medical devices to data hubs such as computers and mobile phones. TI is a promoting member of the Continua Health Alliance and now offers the first Continua-certified USB platform for Agent Devices.
See page 142 for more information.

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

ZigBee® and *Bluetooth*® Low Energy Solutions for Medical Applications

More and more medical devices, especially in patient monitoring and home healthcare, can benefit from wireless technologies such as ZigBee and Bluetooth Low Energy.

The ZigBee standard enables companies to have a simple, reliable, low-cost and low-power standard-based wireless platform for their medical application development.

As an example, with the use of ZigBee wireless sensors, patients can move around in the hospital, or even in their homes, and the sensors will still monitor and send critical health data to the hospital or doctor.

Bluetooth Low-Energy solutions are designed for low-cost, low-power and short range connectivity. The technology enables direct communication to cellular phones, laptops and other Bluetooth enabled devices such as sports and fitness watches, GPS / handhelds, and other personal monitoring devices.

Texas Instruments supports the ZigBee Personal Health (PH) profile as well as the Continua Alliance/ EN11073 profile.

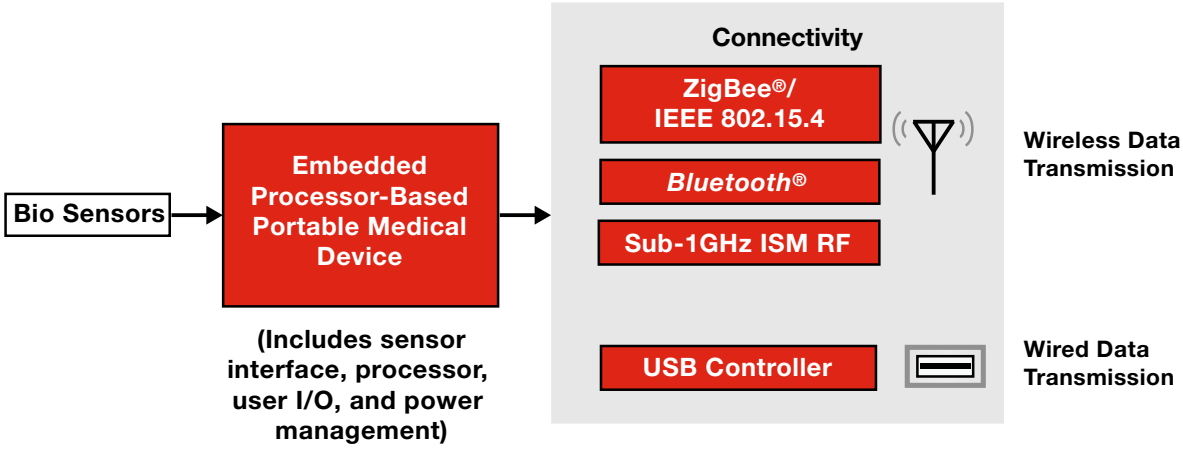
For more information, visit:
www.ti.com/zigbee
www.ti.com/bluetoothlowenergy

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.

Overview (Continued)

Low-Power Wireless (ISM)
TI offers a wide selection of cost-effective, low-power RF solutions for both proprietary and standard-based wireless applications. The portfolio includes RF transceivers, RF transmitters and Systems-on-Chip for short-range 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 below sub-1GHz have limitations that vary from region to region, but their strength is a better range than 2.4GHz with the 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's software portfolio ranges from proprietary solutions with a high degree of design freedom and low complexity to fully interoperable ZigBee® solutions.

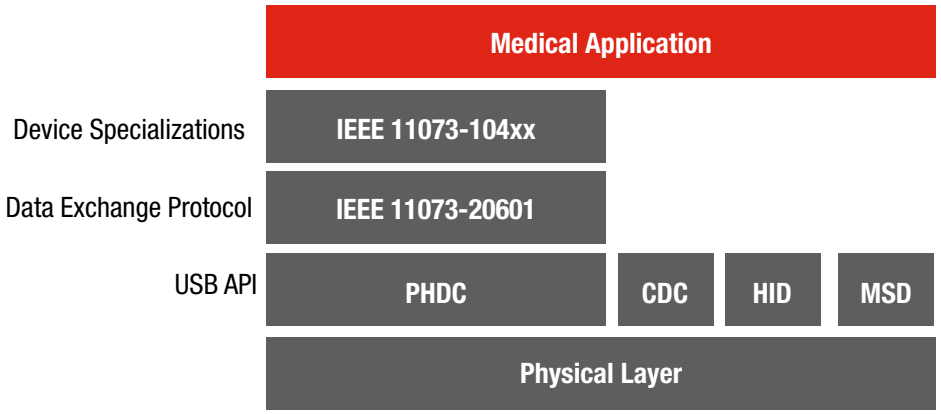
Medical USB Platform

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



Wired Solutions

USB-to-Serial Bridge

TUSB3410

Get samples, datasheets, application reports and evaluation modules at: **www.ti.com/sc/device/TUSB3410**

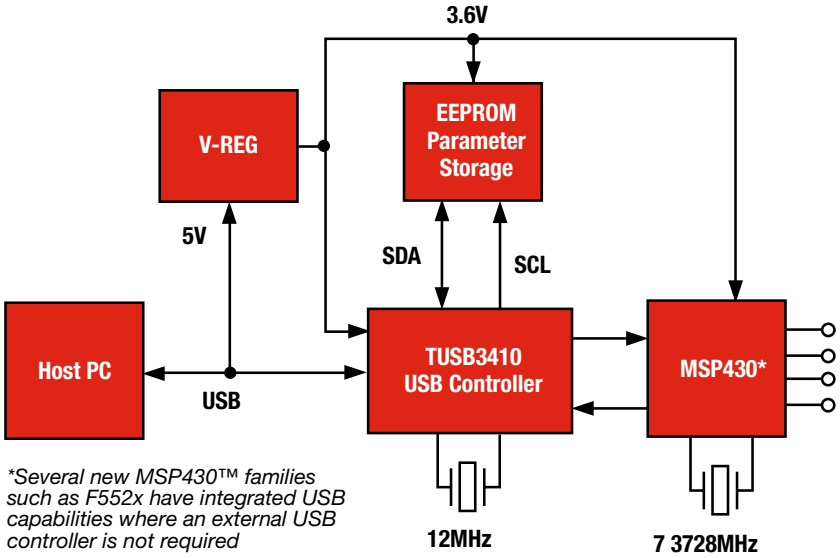
Key Features

- 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 I²C 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.

Wireless Interface, 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						

Wireless Interface, RFID and Tag-it™

Low-Power, Multi-Standard HF RFID Readers

TRF7960,TRF7961

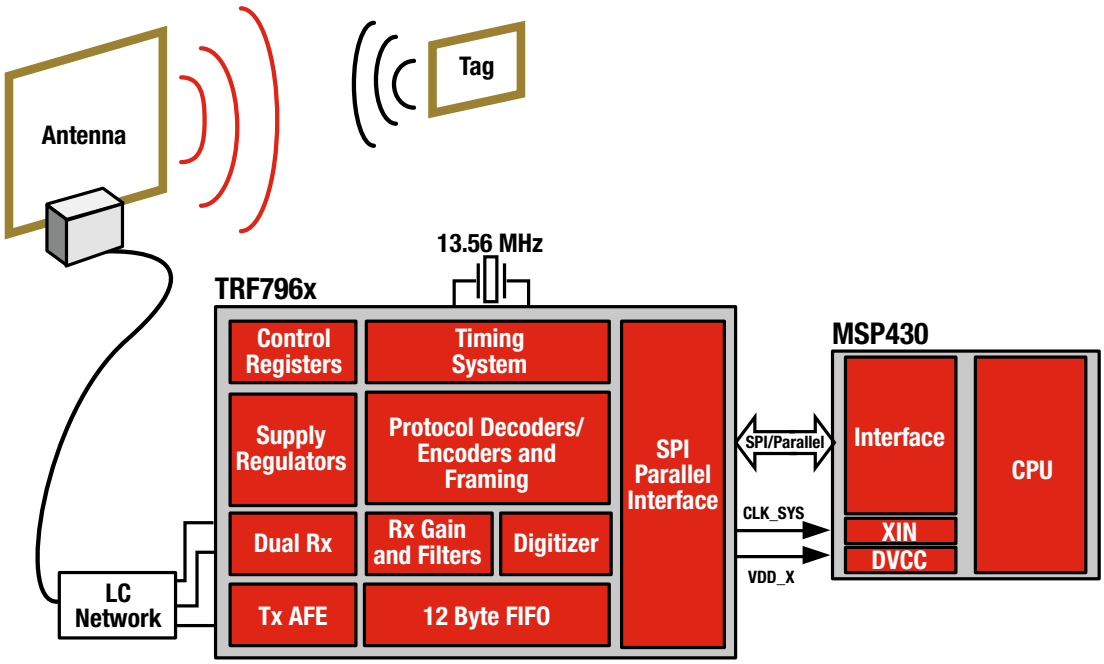
Get samples and datasheets at: **www.ti.com/sc/device/TRF7960** or **www.ti.com/sc/device/TRF7961**

Key Features

- Supports ISO14443A/B, ISO15693 and Tag-it
- High level of integration reduces total cost, BOM and board area
  - Completely integrated protocol handling
  - Separate, internal high-PSRR LDOs for analog, digital and PA sections provide noise isolation for superior read range and reliability
  - Integrated LDO regulator output for MCU
  - Single Xtal system with available output clock for MCU
- Eleven user-accessible and programmable registers
- Low-power device with wide operating voltage range: 2.7V to 5.5V

Complementing the Tag-it™ HF-I family of transponder inlays is TRF7960, a highly integrated analog front end and data framing system for any 13.56MHz RFID reader system. Built-in programming options make TRF7960 useful for a wide range of applications, both in proximity and vicinity RFID systems. A high level of integration, excellent performance, miniature size and multiple low-power modes allow TRF7960 to be used for battery-power-constrained medical applications.

- Programmable output power: 100mW or 200mW
- Parallel 8-bit or serial 4-pin SPI interface with 12-byte FIFO
- Seven user-selectable, ultra-low-power modes
  - Power down: <1µA
  - Standby: 120mA (typical)
  - Active: 10mA (RX only)
- Available MSP430™ software libraries
- Packaging: Ultra-small, 5 x 5mm, 32-pin QFN



Functional block diagram.

Wireless Interface, RFID and Tag-it™

Low-Power, Multi-Standard HF RFID Readers (Continued)

TRF7960,TRF7961

Get samples and datasheets at: **www.ti.com/sc/device/TRF7960** or **www.ti.com/sc/device/TRF7961**

Applications

- Medical
  - Patient and staff authentication
  - Pharmaceutical authentication
  - Product authentication and calibration
  - Remote digital healthcare management
- Asset tracking
- Access control
- Contactless payments
- Prepaid eMetering
- eGovernment

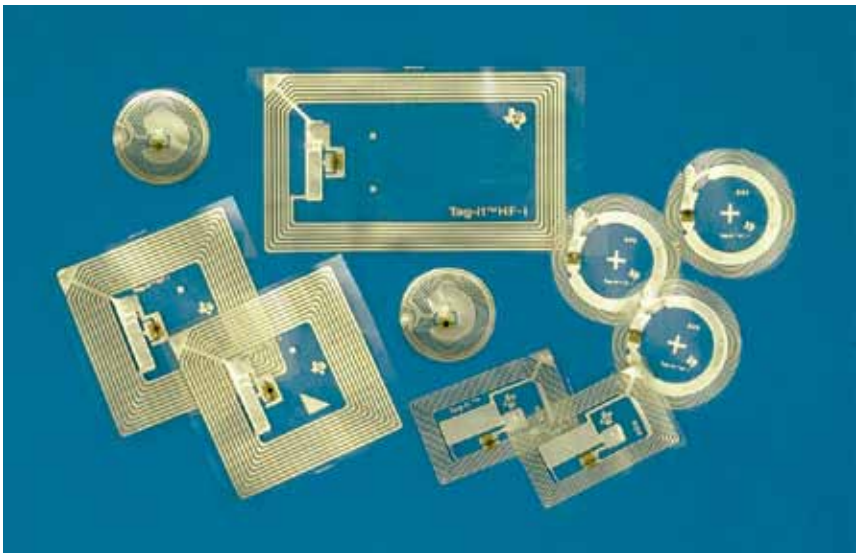
Tag-it™ smart labels bring affordable RFID technology to a wide range of new applications.

TRF7960 Evaluation Module (EVM)

The TRF7960 evaluation tool allows for quicker and simplified system design. The TRF7960 multiple-protocol RFID transceiver incorporates an analog front end, protocol handling, framing, error checking and multiple integrated voltage regulators with other features that allow the reader to be customized/configured to the end application.

TRF7960 EVM features include:

- Fully functional RFID reader with on-board and (optional) off-board antenna capabilities
- GUI that support the ISO14443A, ISO14443B, ISO15693 and Tag-it commands
- Separate LEDs that indicate tag detection—operates in stand-alone mode without GUI



Tag-it™ HF-I family transponder inlays are available in a variety of package options, including square, circular and rectangular (regular and mini).

Low-Power RF Products

Integrated Multi-Channel RF Transceiver

CC1101

Get samples, datasheets, evaluation modules and application reports at: **www.ti.com/sc/device/CC1101**

Key Features

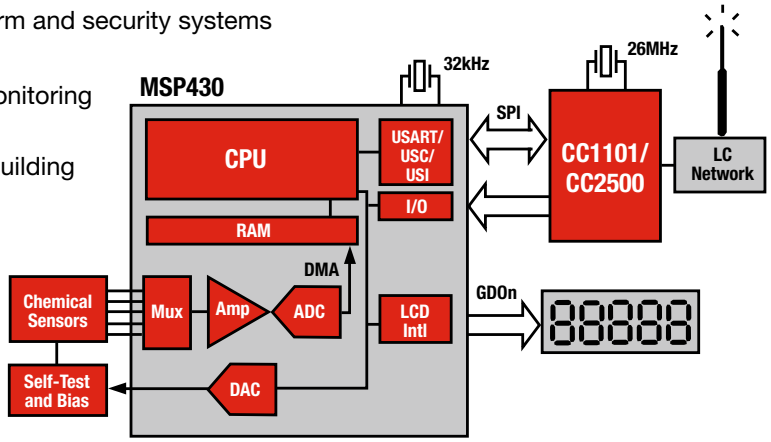
- Sub-1GHz FSK/GFSK/MSK/ASK/ OOK RF transceiver
- 1.2 to 500Kbaud data rate
- Low power, low system cost
- Sleep current: –200nA
- 90µs PLL lock time: –240µs from sleep to RX/TX
- On-chip support for sync word detection, address check, flexible packet length and automatic CRC checking
- Separate 64-byte RX and TX data FIFOs enable burst-mode data transmission
- Suitable for systems targeting compliance with EN 300, 200 (Europe) and FCC CFR Part 15 (U.S.)

Need longer RF range? Try the CC2590/CC1190 2.4GHz and sub 1GHzRF range extender for low-power RF ICs.

The CC1101 is a highly integrated, multi-channel RF transceiver designed for low-power wireless applications in the 315/433/868/915MHz ISM bands. The CC1101 is an upgrade of the CC1100 transceiver with improvements for spurious response, close-in phase noise, input saturation level, output power ramping and extended frequency range.

Applications

- Wireless alarm and security systems
- AMR
- Industrial monitoring and control
- Home and building automation



Example application block diagram – wireless blood gas analyzer.

Sub-1GHz System-on-Chip RF Solution

CC1110/F8/F16/F32

Get samples and datasheets at: **www.ti.com/sc/device/CC1110**

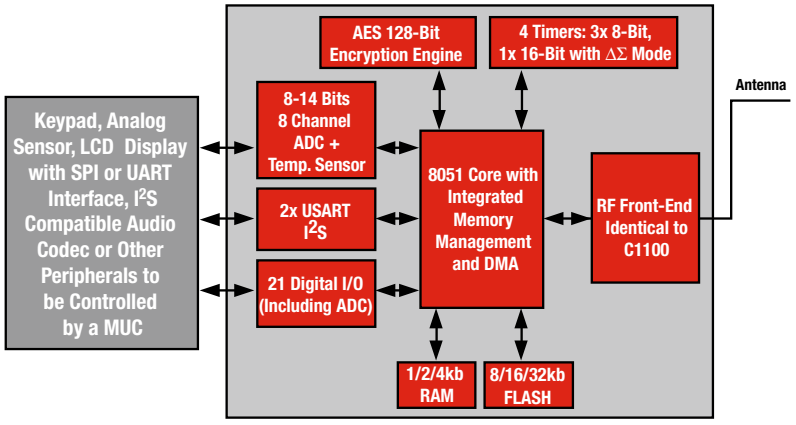
Key Features

- Low current consumption
- High-performance RF transceiver core (same as in the CC1100)
- 8- to14-bit ADC with up to eight inputs
- 21 general I/O pins
- Real-time clock and several timers
- 8/16/32KB in-system programmable Flash
- 1/2/4KB RAM
- Packaging: 6 x 6mm QLP-36

See also the CC2510 and CC2511—2.4GHz, System-on-Chip RF solutions.

Need longer RF range? Try the CC2590/CC2591 2.4GHz RF range extender for low-power RF ICs.
Visit: *www.ti.com/cc2591*

The CC1110 is a low-cost System-on-Chip (SoC) IC designed for low-power and low-voltage wireless communication applications. The CC1110 combines the excellent performance of the CC1100 RF transceiver with an industry-standard enhanced MCU, 8/16/32KB of in-system programmable Flash memory, 1/2/4KB of RAM and many other useful peripherals. Because of several advanced low-power operating modes, the CC1110 is designed for systems where very low power consumption is required.



General-purpose medical device using CC1110. Supports secure RF link with embedded 128-bit AES hardware encryption.

ZigBee® / Bluetooth® Low Energy

ZigBee® and *Bluetooth*® Low Energy Solutions for Medical Applications

The world is going wireless and medical applications are no exception. More and more medical devices, especially patient monitoring, can benefit from wireless technology. ZigBee and *Bluetooth* Low Energy can be utilized in the consumer health, wellness, and medical space across a range of applications.

With the use of ZigBee wireless sensors, the patients can move around in the hospital, or even in their homes, and the sensors will still monitor and send critical health data to the hospital or doctor. Being independent of a patient's exact geographical location has a positive impact on both the patient and the hospital. The ZigBee standard enables companies to have a simple, reliable, low-cost and low-power standard-based wireless platform for their application development.

Bluetooth Low-Energy solutions are designed for low-cost, low-power and short range connectivity. The technology enables direct communication to cellular phones, laptops and other *Bluetooth* enabled devices such as sports and fitness watches, GPS / handhelds, and other personal monitoring devices.

TI is part of the Continua Health Alliance and an active contributor to the evolvement of ZigBee and Bluetooth Low Energy, the wireless standards for medical applications selected by the alliance.

TI's low-power RF portfolio of high-performance RF ICs offers robust and cost-effective wireless connectivity solutions for a variety of medical devices.

IEEE 802.15.4/ZigBee compliant RF ICs

- CC2520: Second-generation 2.4GHz ZigBee/IEEE 802.15.4 RF transceiver
- CC2530/31: True System-on-Chip (SoC) with integrated microcontroller
- CC2530ZNP: ZigBee network processor that communicates with any MCU via an SPI or UART interface
- Reference designs downloadable for all RF ICs

ZigBee Software and Development Tools

- Z-Stack™: ZigBee and ZigBee Pro compliant protocol stack. TI offers this full ZigBee stack free of charge. Z-Stack supports over-the air download (OAD) for firmware upgrades in the field.
- Z-Tool (debug tool)
- Development kits: CC2520DK, CC2530DK and CC2530ZDK
- TIMAC: IEEE 802.15.4 Medium Access Control (MAC) software stack for TI IEEE 802.15.4 transceivers and SoCs

Applications
- Patient monitoring
- Hospital equipment tracking

For more information, visit:
www.ti.com/zigbee

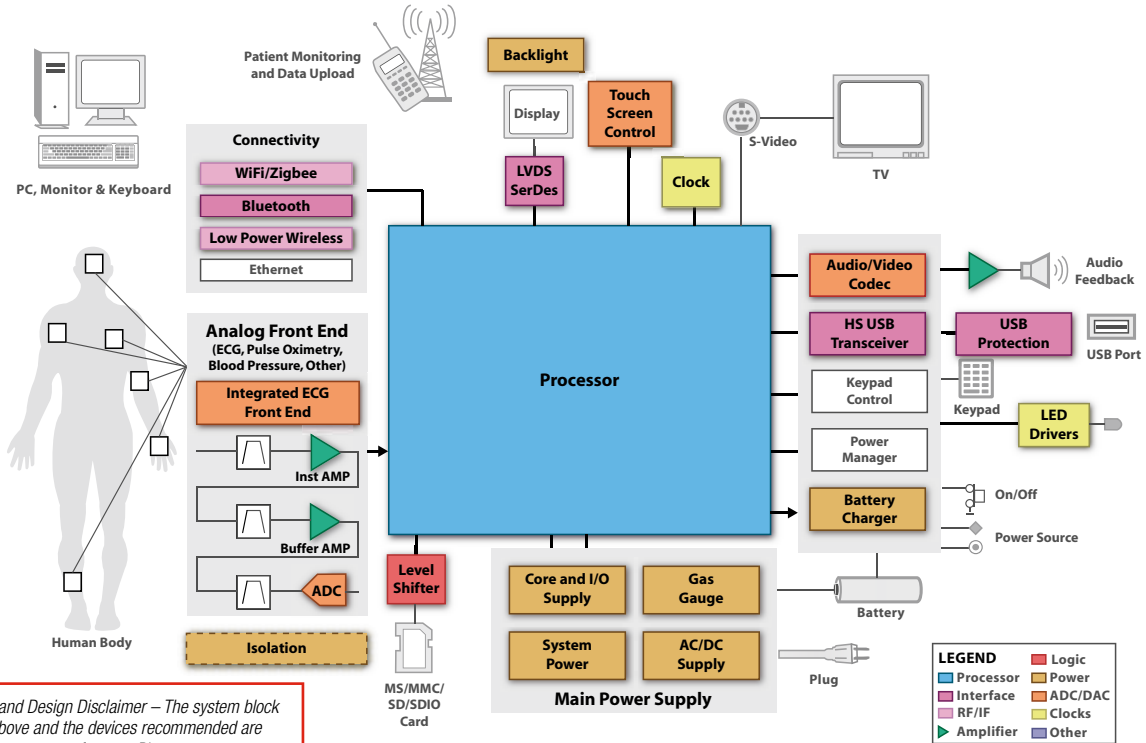
Bluetooth Low Energy IC

- CC2540: 2.4 GHz system-on-chip for Bluetooth low energy applications
- Available in the third quarter of 2010

Bluetooth Low Energy Development Tools
- CC2540DK-MINI
- CC2540DK

Applications
- Consumer Health / Medical
- Bluetooth Low Energy Systems
- Wireless Sensor Systems

For more information, visit:
www.ti.com/bluetoothlowenergy



Multi-parameter patient monitor system block diagram.

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.

Enhanced Products/Die and Wafer Sales Solutions

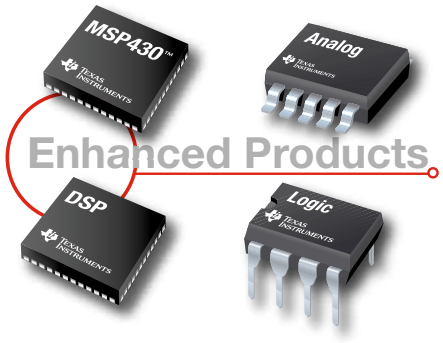
Enhanced Products

TI's Enhanced Product (EP) line offers design flexibility while still meeting HiRel and Medical standards for operating environments where high reliability and long service life are a requirement. The EP line offering can benefit avionic, defense, aerospace, medical, and industrial designers as well as designers in other rugged operating environments and long service life application fields. TI's Enhanced Product line is a commercial of-the-shelf (COTS) solution with the following key benefits:

- Fabrication/assembly controlled baseline
- Extended product change notification (PCN)
- Extended temperature performance (typically -55°C to +125°C)
- Standalone data sheet
- Qualification pedigree
- Product traceability
- Long life cycles

TI's EP products are guaranteed to perform to data sheet specifications in environments that require extended temperatures (typically -55°C to +125°C). To ensure that a device exhibits the highest quality and reliability possible for targeted applications, TI performs the following qualification procedures before the device is released:

- All EP devices undergo extensive requalification
- Qualification data is reviewed and audited for accuracy and compliance
- Reliability and electromigration monitoring is performed at maximum recommended operating conditions in the targeted package.
- Certified test programs & test hardware
- Electrical characterization is performed across specified temperature range
- Package performance is confirmed over extended temperatures (some mold compounds are not suitable for extended temperatures).
- Nickel/palladium/gold/lead finish eliminates "tin whisker" reliability issues
- Knowledgeable expertise in medical related ISO requirements (ISO13485 and ISO14971)
- Certificate of compliance to datasheet electrical specifications
- Available in military (–55°C/125°C), industrial (–40°C/85°C), commercial (0°C/70°C) and custom temperature ranges



Expected from TI's EP line:

- Qualification summary report
- Access to leading-edge commercial technology
- Commitment to the Industrial, Medical, Avionic and Defense markets
- Customer-driven portfolio
- Enhanced obsolescence management

In addition TI will evaluate the release of other TI's catalog devices in an EP versions based on customer requirements.

Get more information about TI's enhanced products at: **www.ti.com/ep**

TI Die/Wafer Solutions

Texas Instruments offers bare die/wafer solutions for applications that require higher levels of integration to reduce board space. TI provides a wide range of products in bare die and wafer form. A variety of testing and qualification options are available based on product maturity and complexity, as well as customer requirements. Typical screening options include DC probe or AC/DC probe at temperature.

TI offers three categories of die screening:

- Commercial wafers and die
  - Standard TI wafer fabrication
- Known Good Die (KGD)
  - Stand alone datasheet and warranted over temperature
- Customer defined qualification
  - QML Class Q (MIL-STD)
  - QML Class V (Space)
  - Additional options available

Typical processing and capabilities include:

- Mount and bond diagrams
- Probed die – 55°C to +210C° or special temp
- Shipping: Tape and reel, waffle packs, custom trays, Gel-Pak®
- Sidewall and visual inspections

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

TI Design Tools

Below you'll find a sampling of the design tools TI offers to simplify your design process. To access any of the following application reports, type the URL **www-s.ti.com/sc/techlit/*litnumber*** and replace *litnumber* with the number in the Lit Number column.
For a complete list of analog application reports, visit: **analog.ti.com/appnotes**
For a complete list of DSP application reports, visit: **www.dspvillage.ti.com/tools**

Title	Lit Number
Amplifiers	
Single-Supply Operation of Isolation Amplifiers	SBOA004
Very Low Cost Analog Isolation with Power	SBOA013
Boost Instrument Amp CMR with Common-Mode Driven Supplies	SBOA014
DC Motor Speed Controller: Control a DC Motor without Tachometer Feedback	SBOA043
PWM Power Driver Modulation Schemes	SLOA092
Thermo-Electric Cooler Control Using a TMS320F2812 DSP and a DRV592 Power Amplifier	SPRA873
Isolation Amps Hike Accuracy and Reliability	SBOA064
Make a –10V to +10V Adjustable Precision Voltage Source	SBOA052
±200V Difference Amplifier with Common-Mode Voltage Monitor	SBOA005
AC Coupling Instrumentation and Difference Amplifiers	SBOA003
Extending the Common-Mode Range of Difference Amplifiers	SBOA008
Level Shifting Signals with Differential Amplifiers	SBOA038
Photodiode Monitoring with Op Amps	SBOA035
Single-Supply Operation of Isolation Amplifiers	SBOA004
Precision IA Swings Rail-to-Rail on Single 5V Supply	SBOA033
Pressure Transducer to ADC Application	SLOA056
Buffer Op Amp to ADC Circuit Collection	SLOA098
Amplifiers and Bits: An Introduction to Selecting Amplifiers for Data Converters	SLOA035B
Diode-Connected FET Protects Op Amps	SBOA058
Signal Conditioning Piezoelectric Sensors	SLOA033A
Diode-Based Temperature Measurement	SBOA019
Single-Supply, Low-Power Measurements of Bridge Networks	SBOA018
Thermistor Temperature Transducer to ADC Application	SLOA052
Signal Conditioning Wheatstone Resistive Bridge Sensors	SLOA034
Low-Power Signal Conditioning for a Pressure Sensor	SLAA034
Interfacing the MSP430 and TMP100 Temperature Sensor	SLAA151
Data Converters	
Configuring I^2S to Generate BCLK from Codec Devices & WCLK from McBSP Port	SLAA413
Interfacing the ADS8361 to the TMS320F2812 DSP	SLAA167
Interfacing the TLC2552 and TLV2542 to the MSP430F149	SLAA168
MSC1210 In-Application Flash Programming	SBAA087
Pressure Transducer to ADC Application	SLOA056
Measuring Temperature with the ADS1216, ADS1217, or ADS1218	SBAA073
SPI-Based Data Acquisition/Monitor Using the TLC2551 Serial ADC	SLAA108A
Implementing a Direct Thermocouple Interface with MSP430x4xx and ADS1240	SLAA125A
Using the ADS7846 Touch-Screen Controller with the Intel SA-1110 StrongArm Processor	SBAA070
Complete Temp Data Acquisition System from a Single +5V Supply	SBAA050
Interfacing the ADS1210 with an 8xC51 Microcontroller	SBAA010
Programming Tricks for Higher Conversion Speeds Utilizing Delta Sigma Converters	SBAA005
Retrieving Data from the DDC112	SBAA026
Selecting an ADC	SBAA004
Synchronization of External Analog Multiplexers with the	SBAA013
The DDC112's Test Mode	SBAA025
Understanding the DDC112's Continuous and Non-Continuous Modes	SBAA024
Thermistor Temperature Transducer to ADC Application	SLOA052

TI Design Tools (Continued)

Title	Lit Number
Low-Power Signal Conditioning for a Pressure Sensor	SLAA034
Data Converters (Continued)	
Signal Acquisition and Conditioning with Low Supply Voltages	SLAA018
An Optical Amplifier Pump Laser Reference Design Based on the AMC7820	SBAA072
Processors/Microcontrollers	
Programming a Flash-Based MSP430 Using the JTAG Interface	SLAA149
Mixing C and Assembler with the MSP430	SLAA140
Implementing an Ultra-Low-Power Keypad Interface with the MSP430	SLAA139
Heart Rate Monitor and EKG Monitor Using the MSP430FG439	SLAA280
A Single-Chip Pulsoximeter Design Using the MSP430	SLAA274
MSP430 Interface to CC1100/2500 Code Library	SLAS325
Choosing an Ultra-Low-Power MCU	SLAA207
ECG, Pulse Oximeter, Digital Stethoscope Development Kits based on C5505 Processor	SPRT523
MSP430 USB Connectivity Using TUSB3410	SLAA276A
MSP430 Flash Memory Characteristics	SLAA334
Wave Digital Filtering Using the MSP430	SLAA331
Implementing a Real-Time Clock on the MSP430	SLAA076A
Interface	
CAN	
A System Evaluation of CAN Transceivers	SLLA109
Introduction to the Controller Area Network	SLOA101
Using CAN Arbitration for Electrical Layer Testing	SLLA123
RS-485	
Interface Circuits for TIA/EIA-485 (RS-485)	SLLA036B
422 and 485 Standards Overview and System Configurations	SLLA070C
RS-485 for E-Meter Applications	SLLA112
TIA/EIA-485 and M-LVDS, Power and Speed Comparison	SLLA106
USB	
VIDs, PIDs and Firmware: Design Decisions When Using TI USB Device Controllers	SLLA154
USB/Serial Applications Using TUSB3410/5052 and the VCP Software	SLLA170
CardBus	
PCI1520 Implementation Guide	SCPA033
LVDS	
LVDS Design Notes	SLLA014A
Reducing EMI with LVDS	SLLA030C
Performance of LVDS Over Cables	SLLA053B
M-LVDS	
Introduction to M-LVDS	SLLA108
M-LVDS Speed Versus Distance	SLLA119
Serdes	
Gigabit Transmission Across Cables	SLLA091
Power Controllers	
DC Brush Motor Control using the TPIC2101	SLIT110
Power Management	
Technical Review of Low Dropout Voltage Regulator Operation and Performance	SLVA072
ESR, Stability, and the LDO Regulator	SLVA115
Extending the Input Voltage Range of an LDO Regulator	SLVA119
High Current LDO Linear Regulators (UCCx81-ADJ, UCCx82-ADJ, UCCx83-ADJ, UCCx85-ADJ)	SLUA256
PowerPAD™ Thermally Enhanced Package	SLMA002

TI Worldwide Technical Support

Internet

TI Semiconductor Product Information Center Home Page
support.ti.com

TI E2E™ Community Home Page
e2e.ti.com

Product Information Centers

Americas	Phone	+1(972) 644-5580
Brazil	Phone	0800-891-2616
Mexico	Phone	0800-670-7544
	Fax	+1(972) 927-6377
	Internet/Email	support.ti.com/sc/pic/americas.htm

Europe, Middle East, and Africa

Phone	
European Free Call	00800-ASK-TEXAS (00800 275 83927)
International	+49 (0) 8161 80 2121
Russian Support	+7 (4) 95 98 10 701

Note: The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Fax	+(49) (0) 8161 80 2045
Internet	support.ti.com/sc/pic/euro.htm

Japan

Phone	Domestic	0120-92-3326
Fax	International	+81-3-3344-5317
	Domestic	0120-81-0036
Internet/Email	International	support.ti.com/sc/pic/japan.htm
	Domestic	www.tij.co.jp/pic

Asia

Phone	
International	+91-80-41381665
Domestic	Toll-Free Number
Australia	1-800-999-084
China	800-820-8682
Hong Kong	800-96-5941
India	1-800-425-7888
Indonesia	001-803-8861-1006
Korea	080-551-2804
Malaysia	1-800-80-3973
New Zealand	0800-446-934
Philippines	1-800-765-7404
Singapore	800-886-1028
Taiwan	0800-006800
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DLP® Products	www.dlp.com	Communications and Telecom	www.ti.com/communications
DSP	dsp.ti.com	Computers and Peripherals	www.ti.com/computers
Clocks and Timers	www.ti.com/clocks	Consumer Electronics	www.ti.com/consumer-apps
Interface	interface.ti.com	Energy	www.ti.com/energy
Logic	logic.ti.com	Industrial	www.ti.com/industrial
Power Mgmt	power.ti.com	Medical	www.ti.com/medical
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Space, Avionics & Defense	www.ti.com/space-avionics-defense
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