Project Code: APM_Wearable_2017

ANALOG DEVICES
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SMART WEARABLE HEALTHCARE DEVICE SOLUTIONS

Smart Wearable Healthcare Devices and Typical Architecture

A wearable healthcare device can be described as an autonomous, noninvasive system that performs a specific medical function such as monitoring or support.

The term wearable implies that the device is either supported directly on the human body or a piece of clothing and has an appropriate design enabling its use as a wearable accessory. In broad terms, this requires the device to have minimal size and weight, functional and power autonomy, to be easy to use, and worn in comfort.

Smart wearable healthcare devices have different product types, like wrist bands, watches, glasses, and other wearable devices. The functions included in these technologies include pedometer, heart rate monitoring, sport performance tracking, biopotential measurement, bio-impedance measurement, blood oxygen measurement, and so on.

Smart wearable healthcare devices are an extension of traditional medical devices. The typical medical device is big, complex, and requires significant power consumption to achieve the high accuracy required by clinical applications. But with improvements in sensor and semiconductor technology, much smaller size and lower power consumption parts have made wearable medical devices possible. Much of the technology used in hospitals and clinics is now available for home use or as wearable devices. Smart, wearable healthcare devices can noninvasively monitor vital signs, and are easy to use and wear. Lighter weight and lower power consumption help create a better user experience.

Design Considerations and Major Challenges

- Size is very important; most wearable devices are light and small size
  - Smaller package
  - Advanced package technology to have more integration
  - Fewer external components
- Super low power consumption
  - Power consumption is very critical for the user experience—the lower, the better
  - Limited battery size for system due to size
  - Low quiescent current chip is good for low power and extended standby time
  - Low power consumption MCU is usually necessary for wearable devices
  - Low power connectivity technology is necessary for wearable devices
- Human engineering design
  - Easy to use
  - Foolproof design
  - High reliability and highly sensitive sensor design
- High reliability
  - Works in various environments
  - Good mechanical design helps prevent devices from being damaged
  - Some devices must be waterproof
- Sensor technology
  - Multisensor fusion
  - The sensor materials selection is important for good biocompatibility
  - High sensitivity with low power
- Connectivity technology
  - Low power Bluetooth,® wi-fi connectivity is necessary to assess other smart devices
  - Data synchronization and application automatically upgrade

Total Solutions from ADI

ADI provides an extensive selection of high integration AFEs, motion sensors, low power MCUs, and power management solutions to maximize product quality and reliability for wearable devices. In addition, ADI provides evaluation boards, simulation tools, and applications expertise to support customer design and development efforts.

Main Signal Chain

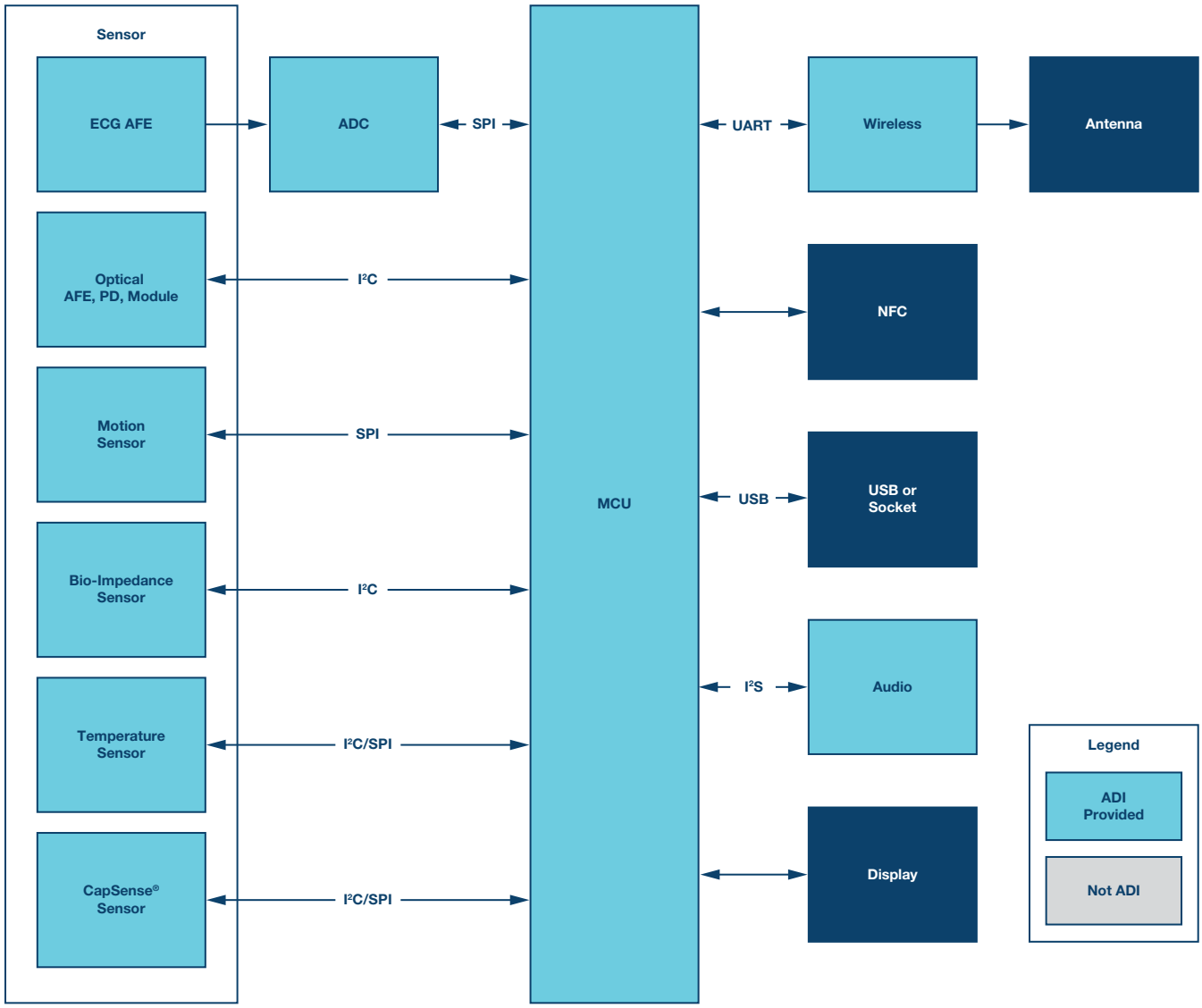

Figure 1. System diagram.

Notes: the signal chains above are representative of healthcare smart wearable devices system. The technical requirements of the blocks vary, but the products listed in the table are representative of ADI's solutions that meet some of those requirements.

Microprocessor	ECG AFE	Optical AFE	Photodiode	Optical Module	Motion Sensor
ADuCM360/ADuCM362/ ADuCM3027/ADuCM3029/ ADuCM4050	AD8232/AD8233/ ADAS1000	ADPD103/ADPD105/ ADPD107	ADPD2210/ADPD2211/ ADPD2212/ADPD2214	ADPD142/ADPD144/ ADPD174/ADPD175	ADXL345/ADXL362/ ADXL363/ADXL355/ ADXL372
Bio-Impedance Sensor	**Temperature Sensor**	**Capacitor Sensor**	**ADC**	**Wireless**	**Audio**
AD5933/ADuCM350	ADT7420/LTC2983	AD7147	AD7091R/AD7124-4/ AD7915/LTC2460/ LTC2462	ADF7020/ADF7024/ ADF7241	SSM2518

Part	Description	Benefits
Processors		
ADuCM360	The ADuCM360 is a fully integrated, 3.9 kSPS, 24-bit data acquisition system that incorporates dual high performance, multichannel sigma-delta (Σ-Δ) analog-to-digital converters (ADCs), a 32-bit ARM® Cortex®-M3 processor, and Flash®/EE memory on a single chip; the ADuCM360 is designed for direct interfacing to external precision sensors in both wired and battery-powered applications; the ADuCM361 contains all the features of the ADuCM360 except that only one 24-bit Σ-Δ ADC (ADC1) is available	Low power precision analog microcontroller, ARM Cortex-M3 with dual Σ-Δ ADCs
ADuCM362	The ADuCM362/ADuCM363 are fully integrated, 3.9 kSPS, 24-bit data acquisition systems that incorporate dual, high performance, multichannel Σ-Δ ADCs, a 32-bit ARM Cortex-M3 processor, and Flash/EE memory on a single chip; the ADuCM362/ ADuCM363 are designed for direct interfacing to external precision sensors in both wired and battery-powered applications; the ADuCM363 contains all the features of the ADuCM362, except that only one 24-bit Σ-Δ ADC (ADC1) is available	Compared with prior product ADuCM360/1, ADuCM362/3 has larger memory with 24KB SRAM and 256KB Flash.
ADuCM3027/ ADuCM3029	The ADuCM302x processor is an ultralow power integrated mixed-signal microcontroller system for processing, control, and connectivity; the microcontroller unit (MCU) system is based on an ARM Cortex-M3 processor, a collection of digital peripherals, embedded SRAM and flash memory, and an analog subsystem that provides clocking, reset, and power management capability in addition to an ADC subsystem; the ADuCM3029 has 256 kB flash—double the size of ADuCM3027	Ultralow power ARM Cortex-M3 MCU with integrated power management and 128 kB of embedded flash memory
ADuCM4050	The ADuCM4050 MCU is an ultralow power integrated microcontroller system with integrated power management for processing, control, and connectivity; the MCU system is based on the ARM Cortex-M4F processor; the MCU also has a collection of digital peripherals, embedded SRAM and flash memory, and an analog subsystem that provides clocking, reset, and power management capability in addition to an ADC subsystem	Ultralow power ARM Cortex-M4F MCU with integrated power management
ECG AFE		
AD8232	The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications; it is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement; this design allows for an ultralow power ADC or an embedded microcontroller to acquire the output signal easily	Single-lead heart rate monitor analog front end
AD8233	The AD8233 is an integrated signal conditioning block for ECG and other biopotential measurement applications. AD8233 is function compatible with prior product AD8232, but with much lower power consumption (50 µA) and smaller size (2 mm × 1.7 mm)	50 µA, 2 mm × 1.7 mm WLCSP, low noise, heart rate monitor for wearable products
ADAS1000	The ADAS1000 measures electrocardiogram (ECG) signals, thoracic impedance, pacing artifacts and lead on/off status and outputs this information in the form of a data frame supplying either lead/ vector or electrode data at programmable data rates; its low power and small size make it suitable for portable, battery-powered applications; the high performance also makes it suitable for higher end diagnostic machines	Low power, 5-electrode ECG analog front end with respiration measurement and pace detection
Optical AFE		
ADPD103	The ADPD103 is a highly efficient photometric front end with an integrated 14-bit ADC and a 20-bit burst accumulator that works in concert with flexible light emitting diode (LED) drivers; the analog front end (AFE) features best-in-class rejection of signal offset and corruption due to modulated interference commonly caused by ambient light	Low power, high accuracy, integrated optical module with ambient light rejection and support LEDs, multifunction photometric front end
ADPD105/ ADPD107	As the upgrade version of ADPD103, the ADPD105/ADPD107 are highly efficient, photometric front ends, each with an integrated 14-bit ADC and a 20-bit burst accumulator that works with flexible LED drivers; the data output and functional configuration occur over a 1.8 V I²C interface on the ADPD105 or SPI on the ADPD107; the control circuitry includes flexible LED signaling and synchronous detection	Low power, high accuracy, integrated optical module with ambient light rejection and support LEDs, multifunction photometric front end
Photometric		
ADPD2210	The ADPD2210 is a low noise current amplifier designed to allow the use of smaller photodiodes by amplifying sensor signal currents by a factor of 24 while adding minimal noise; this amplification provides the system sensitivity of a large photodiode with the benefits of a smaller photodiode; a minimum linearity of 60 dB allows accurate extraction of very small time variant signals on top of large dc or low frequency offsets	Ultralow noise, low power current amplifier
ADPD2211/ ADPD2212/ ADPD2214	The ADPD2211 is an optical sensor optimized for biomedical applications; very low power consumption and near theoretical signal-to-noise ratio (SNR) are achieved by packaging an ultralow capacitance deep junction silicon photodiode operated in zero bias photoconductive mode with a low noise current amplifier 1. The ADPD2211 offers a typical 400 kHz bandwidth performance, which is well suited for use with pulsed excitation 2. The ADPD2212 is similar architecture with ADPD2211 but with larger PD size and IR cut filter 3. The ADPD2214 is also similar architecture with ADPD2211 but with larger PD size and green band-pass filter	Low noise, high sensitivity optical sensor

Part	Description	Benefits
Optical Module		
ADPD142RG/ ADPD142RI	The ADPD142RG/ADPD142RI are complete photometric systems designed to stimulate LEDs and measure the corresponding optical return signals; these systems feature best-in-class rejection of ambient light interference, both dc and ac; each module contains a highly efficient photometric front end, two LEDs, and a photodiode; the front end consists of a control block, an ADC with 20-bit burst accumulator and two flexible, independently configurable LED drivers; the analog front end (AFE) handles return data from each LED on separate data paths, and with the option of separate AFE settings; the data output and functional configuration occur over a 1.8 V I²C interface; the control circuitry includes flexible LED signaling and synchronous detection	Low power, high accuracy, integrated optical module with ambient light rejection and two LEDs
ADPD144RI	Same electrical specification with ADPD142RI, but improved optical/mechanical design for SpO2 application; two drivers are supported for red and infrared LED	Low power, high accuracy, integrated optical module with ambient light rejection and two LEDs
ADPD174	The ADPD174GGI is a complete photometric system designed to measure optical signals from ambient light and from synchronous reflected LED pulses; synchronous measurement offers best-in-class rejection of ambient light interference, both dc and ac; the module integrates a highly efficient photometric front end, three LEDs, and a photodiode (PD); all of these items are housed in a custom package that prevents light from going directly from the LED to the photodiode without first entering the subject	Low power, high accuracy, integrated optical module with ambient light rejection and three LEDs
ADPD175	The ADPD175GGI is a complete photometric system designed to measure optical signals from ambient light and from synchronous reflected LED pulses; ADPD175 is update based on ADPD174; the main improvement is the lastest AFE ADPD105 and optical performance	Integrated optical module with ambient light rejection and three LEDs
Temperature Sensor		
ADT7420	The ADT7420 is a high accuracy digital temperature sensor offering breakthrough performance over a wide industrial range, housed in a 4 mm × 4 mm LFCSP package; it contains an internal band gap reference, a temperature sensor, and a 16-bit ADC to monitor and digitize the temperature to 0.0078°C resolution; the ADC resolution, by default, is set to 13-bit (0.0625°C); the ADC resolution is a user programmable mode that can be changed through the serial interface	±0.25°C accurate, 16-bit digital I²C temperature sensor
LTC2983	The LTC2983 measures a wide variety of temperature; sensors and digitally outputs the result, in °C or °F, with 0.1°C accuracy and 0.001°C resolution; the LTC2983 can measure the temperature of virtually all standard (type B, E, J, K, N, S, R, T) or custom thermocouples and automatically compensate for cold junction temperatures, and linearize the results	Ultrasmall, 16-bit Σ-Δ ADCs with 10 ppm/°C max precision reference
Capacitor Sensor		
AD7147	The AD7147 CapTouch® controller is designed for use with capacitance sensors implementing functions such as buttons, scroll bars, and wheels; the sensors need only one PCB layer, enabling ultrathin applications	CapTouch programmable controller for single-electrode capacitance sensors
ADC		
AD7091R	AD7091R is a 12-bit, successive approximation ADC that offers ultralow power consumption (typically 349 µA at 3 V and 1 MSPS) while achieving fast throughput rates (1 MSPS with a 50 MHz SCLK); the AD7091R uses advanced design and process techniques to achieve this very low power dissipation at high throughput rates; the part also features an on-chip, accurate 2.5 V reference	1 MSPS, ultralow power, 12-bit ADC with on-chip reference in 10-lead LFCSP and MSOP
AD7915	The AD7915/AD7916 are 16-bit, successive approximation ADCs that operate from a single power supply, V_{DD}; they contain a low power, high speed, 16-bit sampling ADC and a versatile serial interface port; on the CNV rising edge, the AD7915/AD7916 sample the voltage difference between the IN+ and IN– pins; the voltages on these pins typically swing in opposite phases between 0 V and V_{REF}	16-bit, 1 MSPS/500 kSPS PulSAR® ADCs in MSOP/LFCSP
AD7124	The AD7124-4 is a low power, low noise, completely integrated analog front end for high precision measurement applications; the device contains a low noise, 24-bit Σ-Δ ADC, and can be configured to have 4 differential inputs or 7 single-ended or pseudo differential inputs; the on-chip low gain stage ensures that signals of small amplitude can be interfaced directly to the ADC	4-channel, low noise, low power, 24-bit, Σ-Δ ADC with PGA and reference
LTC2460/ LTC2462	The LTC2460/LTC2462 are ultratiny, 16-bit ADCs with an integrated precision reference; they use a single 2.7 V to 5.5 V supply and communicate through an SPI interface; the LTC2460 is single ended with a 0 V to V_{REF} input range and the LTC2462 is differential with a $\pm V_{REF}$ input range; they include an integrated oscillator and perform conversions with no latency for multiplexed applications	Ultratiny, 16-bit Σ-Δ ADCs with 10 ppm/°C max precision reference

Part	Description	Benefits
G-Sensor		
ADXL362	ADXL362 is an ultralow power, 3-axis MEMS accelerometer that consumes less than 2 µA at a 100 Hz output data rate and 270 nA when in motion triggered wake-up mode; unlike accelerometers that use power duty cycling to achieve low power consumption, the ADXL362 does not alias input signals by undersampling; it samples the full bandwidth of the sensor at all data rates	Micropower, 3-axis, ±2 *g*/±4 *g*/±8 *g* digital output MEMS accelerometer
ADXL363	The ADXL363 is an ultralow power, 3-sensor combination consisting of a 3-axis MEMS accelerometer, a temperature sensor, and an ADC input for synchronous conversion of an external signal; the entire system consumes less than 2 µA at a 100 Hz output data rate and 270 nA when in motion triggered wake-up mode; the ADXL363 also provides access to an internal ADC for synchronous conversion of an additional analog input	Micropower 3-sensor combination including acceleration and temperature
ADXL355	The ADXL355 is part of a new family of low noise density, low 0 *g* offset drift, low power, 3-axis MEMS accelerometers with selectable measurement ranges; the ADXL355 supports the ±2.048 *g*, ±4.096 *g*, and ±8.192 *g* ranges, and offers industry-leading noise, offset drift over temperature, and long-term stability, enabling precision applications with minimal calibration and with very low power consumption	Low noise, low drift, low power 3-axis accelerometer with digital output
ADXL372	The ADXL372 is an ultralow power, 3-axis, ±200 *g* MEMS accelerometer that consumes 22 µA at a 3200 Hz output data rate (ODR); the ADXL372 does not power cycle its front end to achieve its low power operation and therefore does not run the risk of aliasing the output of the sensor	Micropower, 3-axis, ±200 *g* digital output, MEMS
Bio-Impedance		
ADuCM350	The ADuCM350 is a complete, coin cell powered, high precision, meter on a chip for portable device applications such as point-of-care diagnostics and body-worn devices for monitoring vital signs; the ADuCM350 is designed for high precision potentiostat, current, voltage, and impedance measurement capabilities	16-bit precision, low power meter on a chip with Cortex-M3 and connectivity
AD5933	The AD5933 is a high precision impedance converter system solution that combines an on-board frequency generator with a 12-bit, 1 MSPS ADC; the DFT algorithm returns a real (R) and imaginary (I) data-word at each output frequency	1 MSPS, 12-bit impedance converter, network analyzer
Wireless		
ADF7024	The ADF7024 is an ultralow power, integrated transceiver for use in the license-free ISM bands at 433 MHz, 868 MHz, and 915 MHz; its ease of use and high performance make it suitable for a wide variety of wireless applications; the ADF7024 is suitable for operation under the European ETSI EN300-220 regulation, the North American FCC part 15 regulation, and other similar regulatory standards	Easy to use, lower power, sub-GHz, ISM/SRD, FSK/GFSK, transceiver IC
ADF7020	ADF7020 is a low power, low IF transceiver designed for operation in the license-free ISM bands at 433 MHz, 868 MHz and 915 MHz; it is suitable for circuit applications that meet either the European ETSI EN-300-220 or the North American FCC, part 15.247 and 15.249 regulatory standards	ISM band transceiver IC
ADF7241	The ADF7241 is a highly integrated, low power, and high performance transceiver for operation in the global 2.4 GHz ISM band; it is designed with emphasis on flexibility, robustness, ease of use, and low current consumption; the IC supports the IEEE 802.15.4-2006 2.4 GHz PHY requirements in both packet and data streaming modes	Low power IEEE 802.15.4 zero-IF 2.4 GHz transceiver IC

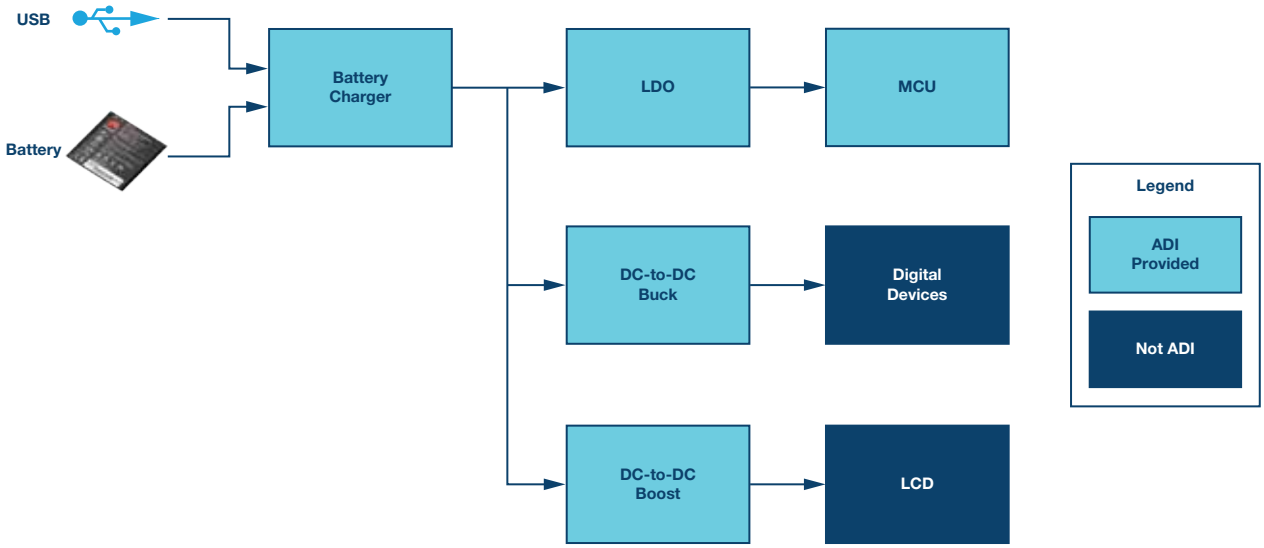

Figure 2. Power supply solution.

Battery Charger	Power Management	LDOs	DC-to-DC Buck	DC-to-DC Boost	DC-to-DC Buck/Boost
ADP5090/ADP5091/ ADP5061/LTC3331/ LTC4123/LTC4065	ADP5310/ADP5350/ LTC3586	ADP160/ADP165/LT3045	ADP5300/ADP5301/ ADP5303/ADP5304/ ADP2102/LTC3388	ADP1607/ADP1612	ADP2503/ADP2504/ LTC3119/LTC3335

Part	Description	Benefits
Battery Charger		
ADP5061	The ADP5061 charger is fully compliant with USB 3.0 and the USB battery charging specification 1.2 and enables charging via the mini USB VBUS pin from a wall charger, car charger, or USB host port; the ADP5061 operates from a 4 V to 6.7 V input voltage range but is tolerant of voltages up to 20 V; the 20 V voltage tolerance alleviates the concerns about the USB bus spiking during disconnect or connect scenarios	Tiny I²C programmable linear battery charger with power path and USB mode compatibility
ADP5090	The ADP5090 is an integrated boost regulator that converts dc power from PV cells or TEGs; the device charges storage elements such as rechargeable Li-Ion batteries, thin film batteries, super capacitors, and conventional capacitors, and powers up small electronic devices and battery-free systems; the ADP5090 provides efficient conversion of the harvested limited power from a 16 µW to 200 mW range with sub-µW operation losses; with the internal cold-start circuit, the regulator can start operating at an input voltage as low as 380 mV; after cold startup, the regulator is functional at an input voltage range of 80 mV to 3.3 V	Ultralow power boost regulator with MPPT and charge management
ADP5091/ ADP5092	The ADP5091/ADP5092 are intelligent, integrated energy harvesting, ultralow power management unit (PMU) solutions that convert dc power from PV cells or TEGs; these devices charge storage elements such as rechargeable Li-Ion batteries, thin film batteries, super capacitors, or conventional capacitors, and power up small electronic devices and battery free systems	Ultralow power energy harvester PMU with MPPT and charge management
LTC3331	The LTC3331 integrates a high voltage energy harvesting power supply plus a buck-boost dc-to-dc converter powered from a rechargeable battery to create a single output supply for alternative energy applications; a 10 mA shunt allows simple charging of the battery with harvested energy while a low battery disconnect function protects the battery from deep discharge	Nanopower buck-boost dc-to-dc with energy harvesting battery charger
LTC4123	The LTC4123 is a low power wireless receiver and a constant-current/constant-voltage linear charger for NiMH batteries; an external programming resistor sets the charge current up to 25 mA; the temperature compensated charge voltage feature protects the NiMH battery and prevents overcharging	Low power wireless charger for hearing aids
LTC4065	The LTC4065-4.4 is a complete constant-current/constant-voltage linear charger for high capacity single-cell lithium-ion batteries with a 4.4 V float voltage; its 2 mm × 2 mm DFN package and low external component count make the LTC4065-4.4 especially well-suited for portable applications	Standalone 750 mA Li-Ion battery charger in 2 mm × 2 mm DFN

Part	Description	Benefits
Power Management		
ADP5310	The ADP5310 combines dual buck regulators and one load switch in a 16-lead TSSOP_EP package that meets demanding performance and board space requirements; the device enables direct connection to a wide input voltage range of 2.7 V to 15.0 V, allowing the use of multiple alkaline/NiMH or lithium cells and other power sources	3-channel, integrated ultralow power solution with dual buck regulators and load switch
ADP5350	The ADP5350 combines one high performance buck regulator for single Li-Ion/Li-Ion polymer battery charging, a fuel gauge, a highly programmable boost regulator for LED backlight illumination, one ultralow quiescent current low dropout (LDO) regulator, and two general-purpose LDO regulators	Advanced battery management PMIC with inductive boost LED and three LDO regulators
LTC3586	The LTC3586/LTC3586-1 are highly integrated power management and battery charger ICs for Li-Ion/ Polymer battery applications; they include a high efficiency current limited switching powerpath manager with automatic load prioritization, battery charger, ideal diode, and four synchronous switching regulators (two bucks, one buck-boost, and one boost)	High efficiency USB power manager with boost, buck-boost, and dual bucks
LDO		
ADP160/ ADP165	The ADP160/ADP165 are ultralow quiescent current, low dropout, linear regulators that operate from 2.2 V to 5.5 V and provide up to 150 mA of output current; the low 195 mV dropout voltage at 150 mA load improves efficiency and allows operation over a wide input voltage range	Ultralow quiescent current 150 mA, CMOS linear regulator
DC-to-DC Buck		
ADP5300/ ADP5301/ ADP5303/ ADP5304	The ADP5300 is a high efficiency, ultralow quiescent current step-down regulator that draws only 180 nA quiescent current to regulate the output at no load; the ADP5300 runs from an input supply voltage range of 2.15 V to 6.50 V, allowing the use of multiple alkaline or NiMH, Li-Ion cells, or other power sources; the output voltage is selectable from 0.8 V to 5.0 V by an external VID resistor and factory fuse; the total solution requires only four tiny external components; the ADP5302/ADP5303/ ADP5304 has different max output current and work frequency	50 mA/500 mA, high efficiency, ultralow power step-down regulator
ADP2102	The ADP2102 is a synchronous step-down dc-to-dc converter that converts a 2.7 V to 5.5 V unregulated input voltage to a lower regulated output voltage with up to 95% efficiency and 1% accuracy; the low duty cycle capability of the ADP2102 is ideal for USB applications or 5 V systems that power up submicron subvolt processor cores; its 3 MHz typical operating frequency and excellent transient response allow the use of small, low cost 1 µH inductors and 2.2 µF ceramic capacitors	Low duty cycle, 600 mA, 3 MHz synchronous, step-down dc-to-dc converter
LTC3388	The LTC3388-1/LTC3388-3 are high efficiency step-down dc-to-dc converters with internal high side and synchronous power switches that draw only 720 nA typical dc supply current at no load while maintaining output voltage regulation	20 V high efficiency nanopower step-down regulator
DC-to-DC Boost		
ADP1607	The ADP1607 is a high efficiency, synchronous, fixed frequency, step-up dc-to-dc switching converter with an adjustable output voltage between 1.8 V and 3.3 V for use in portable applications; the 2 MHz operating frequency enables the use of small footprint, low profile external components; additionally, the synchronous rectification, internal compensation, internal fixed current limit, and current mode architecture allow for excellent transient response and a minimal external part count	2 MHz, synchronous boost dc-to-dc converter
ADP1612	The ADP1612/ADP1613 are step-up dc-to-dc switching con-verters with an integrated power switch capable of providing an output voltage as high as 20 V; with a package height of less than 1.1 mm, the ADP1612/ADP1613 are optimal for space-constrained applications such as portable devices or thin film transistor (TFT) liquid crystal displays (LCDs)	650 kHz /1.3 MHz step-up PWM dc-to-dc switching converter with 1.4 A current limit
DC-to-DC Buck/Boost		
ADP2503/ ADP2504	The ADP2503/ADP2504 are high efficiency, low quiescent current, step-up/step-down dc-to-dc converters that can operate at input voltages greater than, less than, or equal to the regulated output voltage; the power switches and synchronous rectifiers are internal to minimize external part count; at high load currents, the ADP2503/ADP2504 use a current-mode, fixed frequency pulse-width modulation (PWM) control scheme for optimal stability and transient response	600 mA, 2.5 MHz buck-boost dc-to-dc converter
LTC3119	The LTC3119 is a high efficiency, 18 V monolithic buck-boost converter that can deliver up to 5 A of continuous output current; extensive feature integration and very low resistance internal power switches minimize the total solution footprint for even the most demanding applications; a proprietary 4-switch PWM architecture provides seamless low noise operation from input voltages above, equal to, or below the output voltage	18 V, 5 A synchronous buck-boost dc-to-dc converter
LTC3335	The LTC 3335 is a high efficiency, low quiescent current (680 nA) buck-boost dc-to-dc converter with an integrated precision coulomb counter which monitors accumulated battery discharge in long life battery-powered applications; the buck-boost can operate down to 1.8 V on its input and provides eight pin-selectable output voltages with up to 50 mA of output current	Nanopower buck-boost dc-to-dc with integrated coulomb counter

Design Resources

Circuits from the Lab®

- Powering an ECG Front End in Battery-Powered Patient Monitoring Applications (CN-0308)—*analog.com/en/cn-0308*
- Precision 24-Bit, 250 kSPS Single-Supply Sigma-Delta ADC System for Industrial Signal Levels (CN-0310)— *analog.com/en/cn-0310*
- Sensing Low-*g* Acceleration Using the ADXL345 Digital Accelerometer Connected to the ADuC7024 Precision Analog Microcontroller (CN-0133) —*analog.com/en/cn-0133*
- Ultralow Power Standalone Motion Switch (CN-0274)— *analog.com/en/cn-0274*
- Precision Pulse Oximeter LED Current Sinks Using the ADA4505-2 Op Amp, the ADR1581 Shunt Reference, and the ADG1636 Switches (CN-0125)—*analog.com/en/cn-0125*
- 2 MHz Bandwidth PIN Photodiode Preamp with Dark Current Compensation (CN-0272)—*analog.com/en/cn-0272*

Application Notes/Technical Articles

- Multiphysiological Parameter Patient Monitoring (MS-2126)— *analog.com/en/ms-2126.pdf*
- Mitigation Strategies for ECG Design Challenges (MS-2160)— *analog.com/en/ms-2160.pdf*
- Power Management in Health Care Applications (MS-2569)— *analog.com/en/ms-2569.pdf*
- Discussion Between CareFusion and Analog Devices: Optimizing Performance and Lowering Power in an EEG Amplifer (MS-2178)— *analog.com/en/ms-2178.pdf*
- MS-1908: Chip Scale Packaging Helps Portable Medical Devices Save Size and Weight (MS-1908)—*analog.com/en/ms-1908.pdf*
- Biopotential Electrode Sensors in ECG/EEG/EMG Systems— *analog.com/en/ecg-eeg-emg_final.pdf*
- Low Noise Signal Conditioning for Sensor-Based Circuits (MS-2066)—*analog.com/en/ms-2066.pdf*

Design Tools/Forums

- ADC
  - VisualAnalog™ software—*analog.com/en/visualanalog*
  - ADC SPI interface software (SPIController)— *analog.com/en/spicontroller*
  - ADIsimADC modeling tool— *analog.com/ADIsimADC*
- Amplifier
  - DiffAmpCalc™: Differential amplifier calculator— *analog.com/en/diffampcalc*
- PMP
  - ADIsimPower™: Power design tools— *analog.com/en/ADIsimPower*
  - Evaluation board

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