

# ADI RENEWABLE ENERGY—ENERGY STORAGE SOLUTIONS

## ADI Energy Segment Overview

Analog Devices leads the industry in highly accurate and precise signal measurement and control by delivering cost competitive, high quality ICs for reliable metering, measurement, monitoring, and control. These products are used in renewable energy, electrical power transmission, and distribution applications, as well as electric, gas, and water metering. The combination of ADI's proven expertise in optimized system-level signal processing performance and its extensive range of product offerings provides developers with accurate, reliable, and easy to design energy management solutions.

## Main Challenges and System Considerations

- ▶ Reduced \$/Watt system cost
- ▶ Increased grid compliance capability
- ▶ Reduced weight/size through minimization of magnetic and passive
- ▶ Higher reliability and longer lifetime capability
- ▶ High power (>150 kW), high voltage (>1000 V), high density multistage power conversion
- ▶ Bidirectional operation, enabling vehicle to grid
- ▶ Minimization of dc injection current onto the ac grid

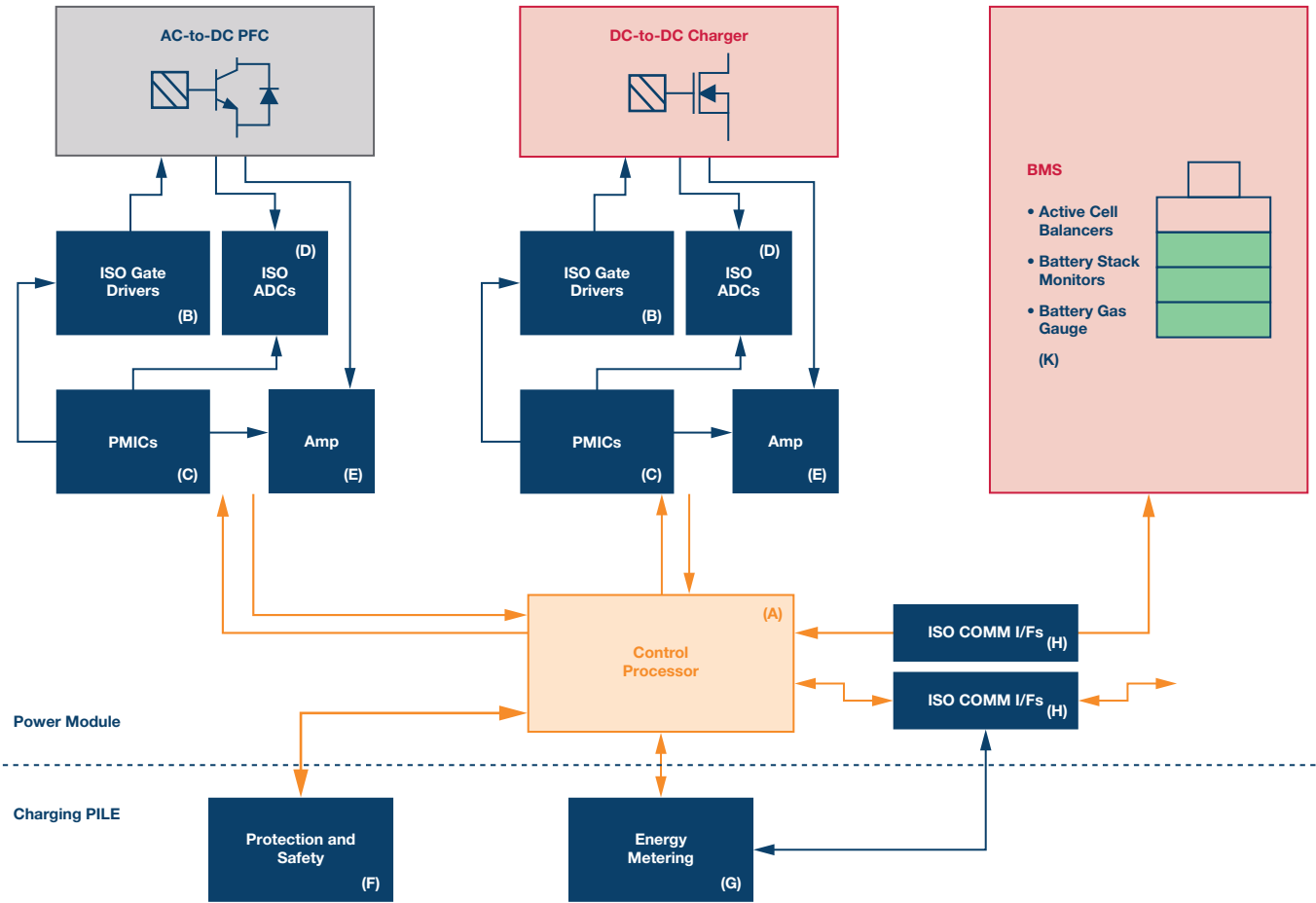
## Energy Storage Application Categories

- ▶ Off-board dc fast chargers
  - Grid-to-vehicle high power chargers
  - Bidirectional high power chargers
  - Bidirectional high power chargers with energy storage units
- ▶ EV charger power modules/racks

## Why Choose ADI

- ▶ Expertise in integrated energy measurement—300 million ADI metrology-based meters deployed
- ▶ Industry leadership in next-generation, higher reliable, isolation technology (*iCoupler*®)
- ▶ 50% of all electrical grid equipment worldwide uses ADI converters
- ▶ Precision measurement of current and voltage through highly accurate converters and amplifiers
- ▶ Enabling power networks and smart grids through the use of high performance processing technology engineered with robustness and reliability
- ▶ System-level mixed-signal conversion and processing, as well as whole signal and power chain products optimized for EV chargers that enable ease of design, reduced time to market, and differentiated end equipment

Energy Storage Signal Chain



| (A) Control Processor                                                                           | (B) Isolated Gate Drivers                                                  | (C) Power Managements ICs                                                                                                               | (D) ADC and Voltage Reference                                                                                                                                                                                                                   | (E) Signal Conditioning |
|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| ADSP-CM411F/ADSP-CM412F/<br>ADSP-CM413F/ADSP-CM416F/<br>ADSP-CM417F/ADSP-CM418F/<br>ADSP-CM419F | ADuM4135/ADuM4136/<br>ADuM4120/ADuM4121/<br>ADuM3223/ADuM4223/<br>ADuM7223 | LT3999/LT3580/LTM8023/<br>LTM8022/LTM8032/LTM8031/<br>ADP2443/ADP1621/ADP1720/<br>ADuM3070/ADuM6000                                     | ADR441/ADR34xx/<br>AD7401A/AD7403                                                                                                                                                                                                               | ADA4077-2/OP2177/AD8066 |
| (F) Protection and Safety                                                                       | (G) Energy Metering                                                        | (H) Communication Interfaces                                                                                                            | (K) Battery Management                                                                                                                                                                                                                          |                         |
| AD7616/AD7091R and AD8604/<br>ADA4666/AD8607/ADA4528/<br>AD8639/AD7606/AD7607/<br>AD7266/AD7265 | ADE7953/ADE7880                                                            | ADM3251E/ADM3252E/<br>ADM101E/ADM3101E/<br>ADM3053E/ADM3054/<br>ADM2481/ADM2483/<br>ADM2484E/ADM2486/<br>ADM2490E/ADM2491E/<br>ADM2587E | Battery Gas Gauge<br>LTC4150/LTC2941/LTC2942/LTC2943/LTC2944<br>Active Cell Balance<br>LTC3300/LTC3305/LT8584<br>Battery Stack Monitor<br>LTC6801/LTC6802/LTC6803/LTC6804/LTC6811/LTC6820<br>Wireless Battery Management<br>LTC6811 and LTC5800 |                         |

## Featured Products

| Part Number                                              | Description                                                             | Key Features                                                                                                                                                                                                          | Benefit                                                                                                |
|----------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Processor</b>                                         |                                                                         |                                                                                                                                                                                                                       |                                                                                                        |
| ADSP-CM411/<br>ADSP-CM412/<br>ADSP-CM413F                | Mixed-signal processor                                                  | Up to 240 MHz ARM® Cortex®-M4, 160 kB SRAM and 1 MB flash memory, 3-way 16-bit ADCs, 2.7 MSPS, integrated FFT, and CORDIC accelerator                                                                                 | ARM processor, usable in a wide range of ecosystems                                                    |
| ADSP-CM416/<br>ADSP-CM417/<br>ADSP-CM418/<br>ADSP-CM419F | Mixed-signal processor                                                  | Up to 240 MHz ARM Cortex-M4, 100 MHz ARM Cortex-M0, 160 kB SRAM and 1 MB flash memory, 6-way 16-bit ADCs, 4.3 MSPS, integrated FFT, and CORDIC accelerator                                                            | ARM processor, usable in a wide range of ecosystems                                                    |
| <b>Isolated Gate Driver</b>                              |                                                                         |                                                                                                                                                                                                                       |                                                                                                        |
| ADuM3223/<br>ADuM4223/                                   | Isolated gate drivers                                                   | 2-channel gate drivers with on-board isolation (working voltage >849 V peak), propagation delay <54 ns, channel-to-channel matching <5 ns                                                                             | Very fast, isolated, 2-channel gate drive for bridge, low propagation delay                            |
| ADuM4135/<br>ADuM4136                                    | Isolated gate drivers for IGBT/MOSFET/SiC/GaN                           | Isolated gate driver with protection function integrated (ULVO, DESAT), up to 5 kV isolation, 100 kV/μs CMTI, 4 amp drive capability, 55 ns propagation delay                                                         | 100 kV/μs CMTI and low propagation delay                                                               |
| ADuM4120                                                 | Isolated, precision gate driver for IGBT/MOSFET/SiC/GaN                 | Precise timing characteristics, 2 A isolated, 5 kV rms isolation in the 6-lead wide body SOIC package, 8 mm creepage                                                                                                  | 150 kV/μs CMTI and low propagation delay                                                               |
| ADuM4121                                                 | Isolated gate drivers for IGBT/MOSFET/SiC/GaN                           | High voltage, isolated gate driver with internal Miller clamp, 2 A output with thermal shutdown                                                                                                                       | 150 kV/μs CMTI and low propagation delay                                                               |
| ADuM7223                                                 | Isolated precision half-bridge driver                                   | 4 A isolated, half-bridge gate driver, to provide independent and isolated high-side and low-side outputs                                                                                                             | High frequency operation: 1 MHz maximum, precise timing characteristics                                |
| <b>Isolation</b>                                         |                                                                         |                                                                                                                                                                                                                       |                                                                                                        |
| ADuM2587E                                                | Isolated RS-485/RS-422 transceiver                                      | Half- or full-duplex, 500 kbps, 5 V or 3.3 V operation, 5 kV isolation                                                                                                                                                | Integrated isolated dc-to-dc converter. ±15 kV ESD protection                                          |
| ADM2484E                                                 | Half-/full-duplex RS-485 transceiver                                    | 5 kV signal isolated, ESD protected, 500 kbps, configurable as half- or full-duplex                                                                                                                                   | ±15 kV ESD protection                                                                                  |
| ADM2490E                                                 | High speed, full-duplex RS-485 transceiver                              | 5 kV signal isolated, high speed (16 Mbps), ESD protected, full-duplex RS-485 transceiver                                                                                                                             | 16 Mbps data rate                                                                                      |
| ADM101E                                                  | Miniature RS-232 transceiver                                            | 460 kbps transmission rate; single 5 V power supply                                                                                                                                                                   | Ultralow power (1 μA) shutdown mode                                                                    |
| ADM3251E                                                 | Isolated single-channel RS-232 line driver/receiver                     | 2.5 kV fully isolated (power and data) RS-232 transceiver, 460 kbps data rate, 1 Tx and 1 Rx                                                                                                                          | isoPower® integrated, isolated dc-to-dc converter                                                      |
| ADM3054                                                  | Isolated CAN transceiver                                                | 5 kV rms signal isolated high speed CAN transceiver with bus protection                                                                                                                                               | High speed data rates of up to 1 Mbps                                                                  |
| ADM3053                                                  | Isolated CAN transceiver                                                | Signal and power isolated CAN transceiver, complies with ISO 11898 standard, high speed data rates up to 1 Mbps                                                                                                       | Integrated isolated dc-to-dc integrated CAN bus single chip solution                                   |
| <b>Energy Meter</b>                                      |                                                                         |                                                                                                                                                                                                                       |                                                                                                        |
| ADE7880                                                  | 3-phase energy meter (with harmonic monitoring)                         | Less than 0.1% error in active and reactive energy over a dynamic range of 1000 to 1, less than 0.2% error in active and reactive energy over a dynamic range of 3000 to 1 at T <sub>A</sub> = 25°C                   | Polyphase energy metering with high performance harmonic analysis                                      |
| ADE7953                                                  | 1-phase energy meter                                                    | Less than 0.1% error in active and reactive energy measurement over a dynamic range of 3000:1, less than 0.2% error in instantaneous I <sub>RMS</sub> and V <sub>RMS</sub> measurements over a dynamic range of 500:1 | High performance, wide dynamic range                                                                   |
| <b>Power Management</b>                                  |                                                                         |                                                                                                                                                                                                                       |                                                                                                        |
| ADuM6000                                                 | Isolated dc-to-dc                                                       | 5 kV isoPower integrated isolated dc-to-dc converter, up to 400 mW output power                                                                                                                                       | Easy to use dc-to-dc converter; combine with the AD7403 to have a shunt-based current sensing solution |
| ADuM3070                                                 | Isolated switch regulator with integrated feedback                      | Regulated adjustable output: 3.3 V to 24 V, up to 80% efficiency                                                                                                                                                      | Isolated PWM feedback with built in compensation                                                       |
| LT3999                                                   | Low noise, 1 A, 1 MHz push-pull dc-to-dc driver with duty cycle control | Wide input operating range: 2.7 V to 36 V; dual 1 A switches with programmable current limit; programmable switching frequency: 50 kHz to 1 MHz                                                                       | High voltage, high frequency dc-to-dc transformer driver providing isolated power                      |

| Part Number                                 | Description                                                               | Key Features                                                                                                                                                                                                                                                                                                                                                                                   | Benefit                                                                                                                                    |
|---------------------------------------------|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| LT3580                                      | DC-to-DC converter                                                        | Boost/inverting dc-to-dc converter with 2 A switch, soft-start, and synchronization                                                                                                                                                                                                                                                                                                            | Easily configurable as a boost or inverting converter                                                                                      |
| LTM8022                                     | DC-to-DC $\mu$ Module <sup>®</sup> power module                           | Wide input voltage range: 3.6 V to 36 V; 0.8 V to 10 V output voltage; 1 A output current                                                                                                                                                                                                                                                                                                      | Power module                                                                                                                               |
| ADP2443                                     | 3 A, 36 V, synchronous step-down dc-to-dc regulator                       | Input voltage: 4.5 V to 36 V; fast minimum on time: 50 ns; programmable switching frequency: 200 kHz to 1.8 MHz                                                                                                                                                                                                                                                                                | Cycle-by-cycle current limit with hiccup protection                                                                                        |
| <i>Protection and Safety</i>                |                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                            |
| AD7266                                      | Multichannel ADC                                                          | The AD7266 is a dual, 12-bit, high speed, low power, successive approximation ADC that operates from a single 2.7 V to 5.25 V power supply and features throughput rates up to 2 MSPS                                                                                                                                                                                                          | Simultaneous sampling with multiplexer                                                                                                     |
| AD7616                                      | 16-channel DAS with 16-bit, bipolar input, dual simultaneous sampling ADC | 92 dB SNR at 500 kSPS (2 $\times$ oversampling), independently selectable channel input ranges, true bipolar: $\pm 10$ V, $\pm 5$ V, $\pm 2.5$ V                                                                                                                                                                                                                                               | Dual simultaneous sampling ADC                                                                                                             |
| AD7606                                      | 8-channel, 16-/14-bit, simultaneous ADC                                   | True bipolar analog input ranges: $\pm 10$ V, $\pm 5$ V, single 5 V analog supply, 2.3 V to 5 V $V_{\text{DRIVE}}$ , 1 M $\Omega$ analog input impedance, analog input clamp protection                                                                                                                                                                                                        | 8-channel simultaneous sampling, single 5 V supply                                                                                         |
| AD8607                                      | Precision dual micropower rail-to-rail input/output amplifier             | Low offset voltage: 40 $\mu$ V typ; low input bias current: 1 pA max; low noise: 25 nV/ $\sqrt{\text{Hz}}$ ; micropower: 50 $\mu$ A/amp max                                                                                                                                                                                                                                                    | Micropower                                                                                                                                 |
| ADA4528                                     | 5.0 V ultralow noise, zero-drift, RRIO                                    | Low offset voltage: 2.5 $\mu$ V maximum; low offset voltage drift: 0.015 $\mu$ V/ $^{\circ}\text{C}$ maximum; low noise: 5.6 nV/ $\sqrt{\text{Hz}}$ at $f = 1$ kHz, $AV = 100$ ; 97 nV p-p at $f = 0.1$ Hz to 10 Hz, $AV = 100$                                                                                                                                                                | Ultralow noise                                                                                                                             |
| <i>Signal Conditioning</i>                  |                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                            |
| ADA4077-2                                   | Amplifier                                                                 | 30 V, 4 MHz, 7 nV/ $\sqrt{\text{Hz}}$ , low offset and drift, high precision dual amplifiers                                                                                                                                                                                                                                                                                                   | Highly precise dual amplifier                                                                                                              |
| AD8066                                      | Amplifier                                                                 | High performance, 145 MHz highly precise dual amplifier                                                                                                                                                                                                                                                                                                                                        | High speed: 145 MHz, $-3$ dB bandwidth ( $G = +1$ )                                                                                        |
| <i>ADC and Voltage Reference</i>            |                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                            |
| AD7403                                      | Isolated $\Sigma$ - $\Delta$ modulator                                    | Isolated $\Sigma$ - $\Delta$ modulator with 5 kV isolation, $\pm 250$ mV ( $\pm 320$ mV full scale), 88 dB, and 14-bit +ENOB                                                                                                                                                                                                                                                                   | Voltage reference featuring ultralow noise, high accuracy, and low temperature drift performance                                           |
| ADR34xx                                     | Voltage reference                                                         | Maximum temperature coefficient: 8 ppm/ $^{\circ}\text{C}$ , operating temperature range: $-40^{\circ}\text{C}$ to $+125^{\circ}\text{C}$ , output current: $+10$ mA source/ $-3$ mA sink                                                                                                                                                                                                      | 8 ppm max, low cost voltage reference                                                                                                      |
| ADR441                                      | Voltage reference                                                         | Voltage reference featuring ultralow noise, high accuracy, and low temperature drift performance                                                                                                                                                                                                                                                                                               | Ultralow noise (0.1 Hz to 10 Hz)                                                                                                           |
| <i>Battery Management</i>                   |                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                                            |
| LTC6801/<br>LTC6802/<br>LTC6803/<br>LTC6804 | Battery stack monitor                                                     | Monitors up to 12 Li-ion cells in series (60 V max) stackable architecture enables $>1000$ V systems, 1% maximum overvoltage detection level error, adjustable overvoltage and undervoltage detection, self-test features that guarantee accuracy, and robust fault detection using differential signals                                                                                       | Designed for automotive and transportation applications AEC-Q100 generic family data available for specific packages                       |
| LTC4150                                     | Battery gas gauge                                                         | Indicates charge quantity and polarity; $\pm 50$ mV sense voltage range                                                                                                                                                                                                                                                                                                                        | The LTC4150 is intended for 1-cell or 2-cell Li-ion and 3-cell to 6-cell NiCd or NiMH applications                                         |
| LTC2941/<br>LTC2942/<br>LTC2943/<br>LTC2944 | Battery gas gauge                                                         | Indicates accumulated battery charge and discharge, high accuracy analog integration, high-side sense, and 1% charge accuracy                                                                                                                                                                                                                                                                  | Designed for automotive and transportation applications AEC-Q100 generic family data available for specific packages                       |
| LTC3300                                     | Active cell balance                                                       | Bidirectional synchronous flyback balancing of up to 6 Li-ion or LiFePO4 cells in series, up to 10 A balancing current (set by externals), integrates seamlessly with the LTC680x family of multicell battery stack monitors, bidirectional architecture minimizes balancing time and power dissipation, up to 92% charge transfer efficiency stackable architecture enables $>1000$ V systems | Designed for automotive and transportation applications AEC-Q100 generic family data available for specific packages                       |
| LT8584                                      | Active cell balance                                                       | 2.5 A typical average cell discharge current, integrated 6 A, 50 V power switch, integrates seamlessly with LTC680x family: no additional software required, selectable current and temperature monitors, ultralow quiescent current in shutdown, engineered for ISO 26262 compliant systems                                                                                                   | 2.5 A monolithic active cell balancer with telemetry interface                                                                             |
| LTC6811                                     | Battery stack monitor                                                     | Pin-compatible upgrade from the LTC6804, measures up to 12 battery cells in series, 1.2 mV maximum total measurement error, stackable architecture supports 100s of cells built-in isoSPI <sup>™</sup> interface                                                                                                                                                                               | A multicell battery stack monitor that measures up to 12 series connected battery cells with a total measurement error of less than 1.2 mV |
| LTC6820                                     | Battery stack monitor                                                     | 1 Mbps isolated SPI data communications, simple galvanic isolation using standard transformers, bidirectional interface over a single twisted pair, supports cable lengths up to 100 meters, very low EMI susceptibility and emissions, configurable for high noise immunity or low power engineered for ISO 26262 compliant systems                                                           | Designed for automotive and transportation applications AEC-Q100 generic family data available for specific packages                       |

## Reference Design and Demo Boards

### Circuits from the Lab® Reference Circuits for Energy Management

- ▶ 500 V Common-Mode Voltage Current Monitor (CN-0218)—[analog.com/en/cn-0218](http://analog.com/en/cn-0218)

More reference circuits are available at:

[analog.com/circuits](http://analog.com/circuits)

### Technical Articles/Application Notes

- ▶ Recommendations for Control of Radiated Emissions with *isoPower* Devices (AN-0971)—[analog.com/en/AN-0971](http://analog.com/en/AN-0971)
- ▶ Wiki Links—[wiki.analog.com](http://wiki.analog.com)
- ▶ ADuM4135 gate driver module (Microsemi)—[wiki.analog.com/resources/eval/eval-microsemi-sic-module](http://wiki.analog.com/resources/eval/eval-microsemi-sic-module)

### SOH\SOC Estimation Techniques and Algorithm

*A Closer Look at State of Charge (SOC) and State of Health (SOH) Estimation Techniques for Batteries*

## Design Tools/Forums

- ▶ ADI's Fastest and Most Accurate DC-to-DC Power Management Design Tool (ADIsimPower™)—[analog.com/ADIsimPower](http://analog.com/ADIsimPower)
- ▶ Online Technical Support Community (EngineerZone®)—[ez.analog.com](http://ez.analog.com)
- ▶ ADSP-CM41x EZ-Board® and EZ-Kit Lite® Evaluation Hardware—[analog.com/en/cm419f-ez](http://analog.com/en/cm419f-ez)

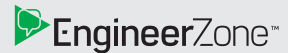
If You Need More ADI Energy Applications and Products Information, Please Visit:

[analog.com/en/solar-inverters](http://analog.com/en/solar-inverters)

### Technical Support

Engage with the Analog Devices technology experts in our online support community. Ask your toughest design questions, browse FAQs, or join a conversation.

[ez.analog.com](http://ez.analog.com)



### Customer Interaction Center

[cic.asia@analog.com](mailto:cic.asia@analog.com)

### Free Samples

[analog.com/sample](http://analog.com/sample)

### Technical Hotline

1-800-419-0108 (India)

886-2-2650-2888 (Taiwan)

82-2-368-2500 (Korea)

#### Analog Devices, Inc. Worldwide Headquarters

Analog Devices, Inc.  
One Technology Way  
P.O. Box 9106  
Norwood, MA 02062-9106  
U.S.A.  
Tel: 781.329.4700  
(800.262.5643, U.S.A. only)  
Fax: 781.461.3113

#### Analog Devices, Inc. Europe Headquarters

Analog Devices GmbH  
Otto-Aicher-Str. 60-64  
80807 Munich  
Germany  
Tel: 49.89.76903.0  
Fax: 49.89.76903.157

#### Analog Devices, Inc. Japan Headquarters

Analog Devices, KK  
New Pier Takeshiba  
South Tower Building  
1-16-1 Kaigan, Minato-ku,  
Tokyo, 105-6891  
Japan  
Tel: 813.5402.8200  
Fax: 813.5402.1064

#### Analog Devices, Inc. Asia Pacific Headquarters

Analog Devices  
5F, Sandhill Plaza  
2290 Zuchongzhi Road  
Zhangjiang Hi-Tech Park  
Pudong New District  
Shanghai, China 201203  
Tel: 86.21.2320.8000  
Fax: 86.21.2320.8222

©2018 Analog Devices, Inc. All rights reserved. Trademarks and registered trademarks are the property of their respective owners. Ahead of What's Possible is a trademark of Analog Devices.  
BR20199-0-4/18

[analog.com](http://analog.com)



AHEAD OF WHAT'S POSSIBLE™