# Amplifiers and Comparators

## Product Guide


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MAXIM
INNOVATION DELIVERED®

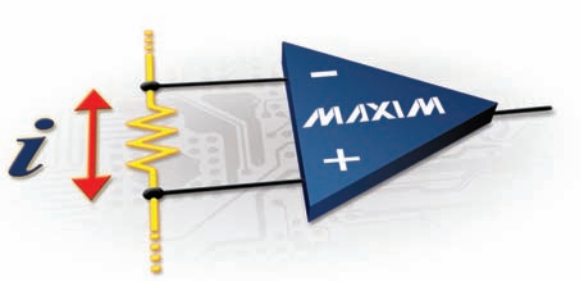
# Consumer products

## Low-power, high-performance, space-efficient amplifiers and comparators offer design flexibility for consumer equipment

In handheld consumer equipment, size and power consumption are of critical importance. This is true both for end products and each internal component. Consumers today also expect mobile devices to get progressively smaller and thinner, all the while supporting more functionality and longer operation. Knowing this, Maxim has designed a broad portfolio of small ICs that offer the versatility and low power so paramount for today's consumer designs.

### Current monitoring

Current-sense amplifiers (CSAs) are used in a variety of applications in handheld devices. CSAs monitor a battery's current to estimate battery life, determine system's state of health, or, less commonly, monitor solar cell efficiency. In other designs, CSAs provide overcurrent protection and identify unexpected fault conditions, such as opens or shorts.




Handheld consumer devices are characterized by their small form factors and limited battery life. It is no surprise, therefore, that a CSA must consume only negligible space and power. With its 1µA supply current and ultra-small UCSP™ package, the MAX9634 provides excellent performance in a small size. This is just one part—Maxim offers the industry's most complete portfolio of current monitors for portable devices.

### Op amps and comparators

Op amps and comparators perform a wide variety of tasks in handheld equipment. Once again, regardless of the application, size and power consumption are critical specifications when selecting these devices. Op amps are used for amplification, filtering, or buffering in sensor interfaces. Comparators often provide voltage detection in jack-detect and accessory-control applications. Maxim offers a wide variety of ultra-low-power (< 1µA) op amps and comparators in the industry's most space-efficient packages, including a 1mm x 1mm UCSP.

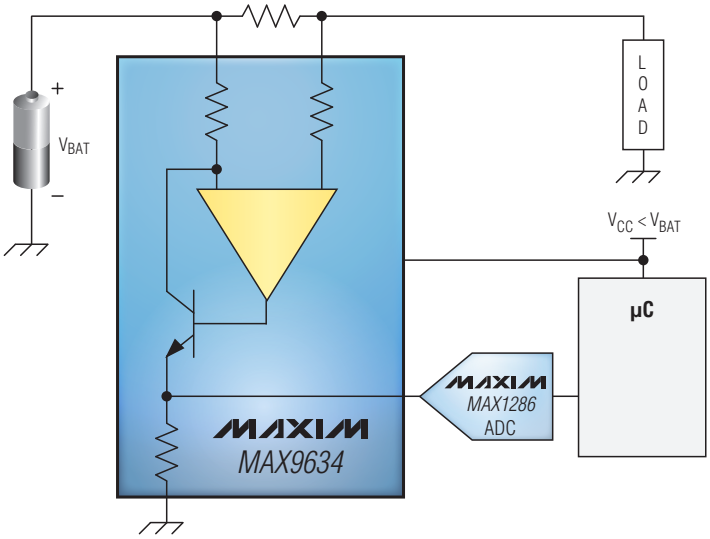
# Ultra-low-power, 1mm x 1mm, current-sense amplifier saves power and space in portable devices

## High precision for demanding applications

### MAX9634

The MAX9634 high-side current-sense amplifier offers precision accuracy of less than 250µV (max) input offset voltage ($V_{OS}$) and less than ±0.5% (max) gain error. Quiescent supply current is an ultra-low 1µA. The MAX9634 is packaged in a tiny, 1mm x 1mm UCSP or a 5-pin SOT23. It is ideal for notebook computers, cell phones, PDAs, and all battery-operated portable devices where accuracy, low quiescent current, and small size are critical.

- **Saves power and space in portable applications**
  - 1µA (max) quiescent current over temperature
  - Tiny, 1mm x 1mm, 4-bump UCSP
- **Provides high performance for a wide range of applications**
  - Low 250µV (max) $V_{OS}$ enables use of small sense resistor for minimally invasive current sensing
  - Wide, 1.6V to 28V input common-mode range is ideal for handheld and computing applications




*The MAX9634 provides low-power battery-current monitoring.*

**To learn more about current-sense amplifiers, go to:**
**www.maxim-ic.com/CSAs**

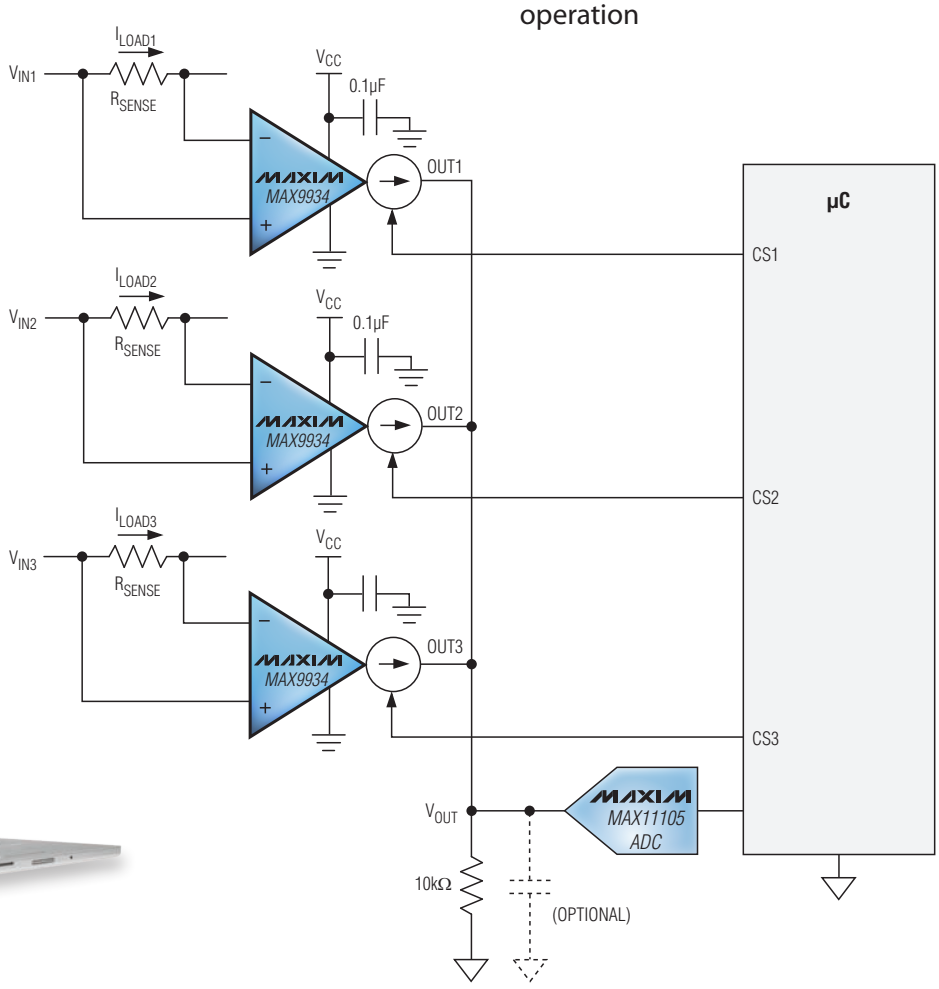
# Get maximum accuracy in precision applications

## High-precision current-sense amplifier with current-output and chip-select functions for multiplexing

### MAX9934

The MAX9934 is a high-precision, low-voltage, high-side current-sense amplifier. This device is ideal for bidirectional (charge/discharge) and unidirectional current measurements in battery-powered portable and laptop devices. $V_{OS}$ is a low 10µV (max) at +25°C across the -0.1V to +5.5V input common-mode voltage range, and is independent of $V_{CC}$. The MAX9934's precision-input specification allows the use of very small, ±10mV (full-scale, typ) sense voltages for minimally invasive current sensing. Also, the low 10µV $V_{OS}$ allows the user to accurately monitor low standby currents.

- **Provides ultimate precision for high-accuracy current monitoring**
  - Ultra-low, 10µV (max) $V_{OS}$ enables use of small sense resistor for minimally invasive current sensing
  - Gain error of < ±0.25%
- **Saves space in portable applications**
  - Tiny, 1mm x 1.5mm, 6-bump UCSP
- **Unique features allow flexibility of system design**
  - Current output allows $R_{OUT}$ selection for gain flexibility
  - Supports bidirectional or unidirectional operation



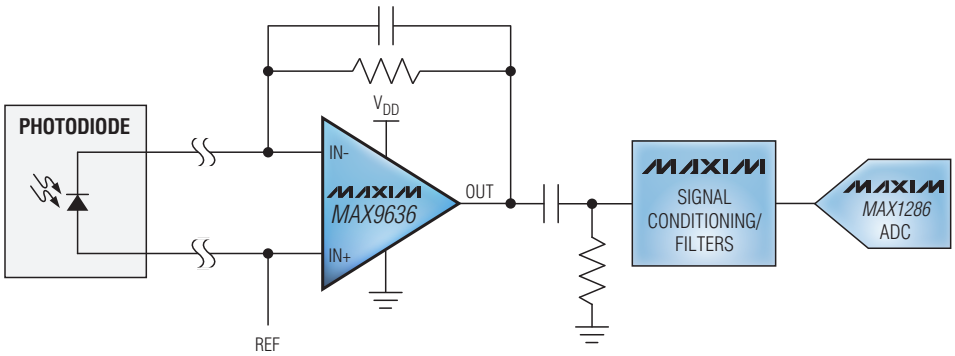

*The MAX9934, used here for unidirectional operation, features a chip-select option that can be used to deselect the output-current source, achieving a high-impedance output with 0.1nA leakage current.*

# 3V/5V op amps provide low-power, cost-effective performance when low noise and low $I_{BIAS}$ are critical

## MAX9636/MAX9637*/MAX9638*

The MAX9636/MAX9637/MAX9638 are single-supply, CMOS-input op amps that have rail-to-rail I/O (RRIO). With wide bandwidth at a low quiescent current, they are suitable for a broad range of battery-powered applications including portable medical instruments, portable media players, and smoke detectors. The combination of extremely low input-bias currents, low input-current noise, and low input-voltage noise allows interfacing to high-impedance sources such as photodiode and piezoelectric sensors.

- **Low noise and low $I_{BIAS}$ enable precision interfaces**
  - 38nV/√Hz input-voltage noise
  - 50fA/√Hz input-current noise
  - Ultra-low, 0.1pA bias current
- **Optimized speed-to-power ratio provides exceptional low-power performance**
  - 36µA quiescent current
  - Wide 1.5MHz bandwidth
  - 2.1V to 5.5V supply range
- **Save space in portable applications**
  - MAX9636: 6-pin SC70 (2mm x 2mm)
  - MAX9637: 8-pin SC70 (2mm x 2mm)
  - MAX9638: 10-pin UTQFN (1.4mm x 1.8mm)




*The MAX9636 provides low < 0.1pA $I_{BIAS}$, wide 1.5MHz gain-bandwidth product (GBWP), and low < 36µA current consumption.*

*Future product—contact factory for availability.

# Ultra-small comparators provide simple, low-power solutions when board space is limited

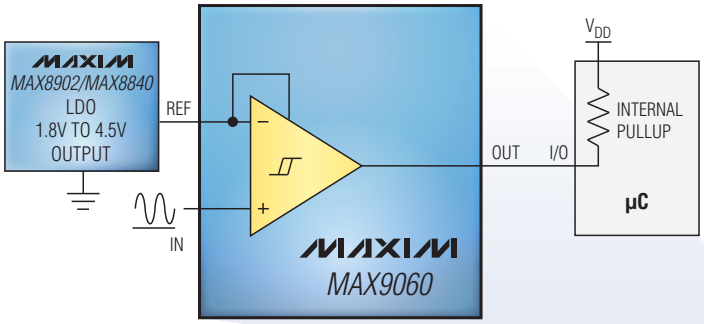
## Versions with internal or external references add design flexibility

### MAX9060–MAX9064

The MAX9060–MAX9064 are small single comparators that are ideal for a wide variety of portable electronics with extremely tight board space and power constraints. Typical applications include cell phone and media player jack detection, and notebook voltage monitoring.

The MAX9060/MAX9061 use an external reference, while the MAX9062/MAX9063/MAX9064 integrate a 0.2V reference. These comparators are offered in both tiny, 1mm x 1mm, 4-bump UCSP (as small as two 0402 resistors) and 5-pin SOT23 packages.

- **Ultra-low power consumption**
  - 50nA (MAX9060/MAX9061)
  - 400nA (MAX9062/MAX9063/MAX9064)
- **Save space in portable applications**
  - Ultra-small, 1mm x 1mm UCSP
- **Support low-voltage operation**
  - 0.9V to 5.5V (MAX9060/MAX9061)
  - 1.0V to 5.5V (MAX9062/MAX9063/MAX9064)




*The MAX9060 provides ultra-low, 1µA (max) quiescent current over temperature.*

**To learn more about low-power comparators, go to:**
**www.maxim-ic.com/comps**

## Current-sense amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9634 | Ultra-low-power current-sense amp | 1µA supply current; 1mm x 1mm UCSP; 250µV (max) $V_{OS}$; 28V common-mode range | Ultra-low supply current is ideal for "always-on" applications; most space-efficient current-sensing solution |
| MAX9934 | Ultra-precision current-sense amp | 10µV (max) $V_{OS}$; 1mm x 1.5mm UCSP; 5.5V common-mode range; current output | Ultra-low $V_{OS}$ enables precision monitoring with small sense resistor; current output allows adjustable gain; chip-select function allows multiplexing of multiple MAX9934 devices |
| MAX9928F/29F | Low-power, bidirectional current-sense amps | 20µA supply current; 1mm x 1.5mm UCSP; 400µV (max) $V_{OS}$; 28V common-mode range; current output (MAX9928F) | SIGN output for true bidirectional sensing; current output allows adjustable gain |
| MAX9937 | General-purpose, low-power current-sense amp | 20µA supply current; 5-pin SC70; 28V common-mode range | Low-power, general-purpose solution minimizes BOM cost |

## Operational amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9636/37*/38* | Low-power, low-noise, CMOS-input, rail-to-rail I/O (RRIO) op amps | 38nV/√Hz input-voltage noise; 50fA/√Hz input-current noise; ultra-low 0.1pA bias current; 36µA supply current; 1.5MHz bandwidth; shutdown mode | Low noise and low $I_{BIAS}$ are ideal for sensitive sensor interface applications |
| MAX9617–20 | High-efficiency op amps with RRIO | 10µV (max) $V_{OS}$; 59µA supply current; 1.5MHz bandwidth; dual version in 8-pin SC70; shutdown mode (MAX9619) | Industry-leading combination of precision, low power, size, and bandwidth |
| MAX4230–34 | High-output-drive, RRIO op amps | 200mA output drive; 10MHz bandwidth; UCSP version available; shutdown mode | RF immunity helps avoid EMI issues; high output current is ideal for driver applications |
| MAX9910–13 | 200kHz, 4µA, RRIO op amps with shutdown | 200kHz bandwidth; 4µA supply current; shutdown mode | Optimized speed-to-power ratio minimizes current consumption |
| MAX9914–17 | 1MHz, 20µA, RRIO op amps with shutdown | 1MHz bandwidth; 20µA supply current; shutdown mode | Optimized speed-to-power ratio minimizes current consumption |
| MAX4470 | Ultra-low-power op amp with rail-to-rail outputs | 0.75µA supply current; 9kHz bandwidth | Low power extends battery life in portable applications |

## Comparators

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9060–64 | Ultra-small nanopower comparators | < 1µA supply current; 1mm x 1mm UCSP; versions with internal (0.2V) or external reference | Ultra-low supply current is ideal for "always-on" applications |
| MAX9025–28 | Nanopower, Beyond-the-Rails™ comparators | < 1µA supply current; 1mm x 1.5mm UCSP; versions with internal (1.2V) or external reference | Ultra-low supply current is ideal for "always-on" applications; accepts input voltages 200mV beyond the rails to provide application flexibility |

**www.maxim-ic.com/amps-comps**

Beyond-the-Rails is a trademark of Maxim Integrated Products, Inc.
*Future product—contact factory for availability.

# Computing applications

## Space-efficient, low-power, high-performance amplifiers and comparators offer design flexibility for computing equipment

Computing devices have a wide variety of application requirements that vary depending on the end equipment. For instance, precision current monitoring is important in servers that monitor the use and allocation of limited or highly valued resources. Accurate fault protection assures the safety of computing equipment, from servers to netbooks and tablets, to PDAs and PCs. Maxim, an industry leader in performance and power savings, offers a wide selection of highly efficient solutions for next-generation computing applications.

### Current monitoring

Current-sense amplifiers are used in computing equipment to help implement system power-management schemes. In tablets and notebooks, system power management is necessary for maximizing battery life and ensuring optimum performance for entire systems. Servers require aggressive power management to minimize heat dissipation while reducing electricity consumption. Maxim's extensive current-monitoring portfolio can accurately measure the small standby currents of power-limited tablets or netbooks, as well as meet the demanding current-monitoring requirements of power-hungry servers.

### Op amps and comparators

Op amps and comparators have various general-purpose roles in computing equipment. Op amps can amplify, filter, or buffer signals. Comparators are used in jack-detect, accessory-control, and overvoltage-protection (OVP) applications. Maxim offers one of the largest lines of micropower, small form factor (SFF), performance op amps and comparators in the industry, supporting the demanding needs of computing equipment and alleviating power-budget and size concerns.

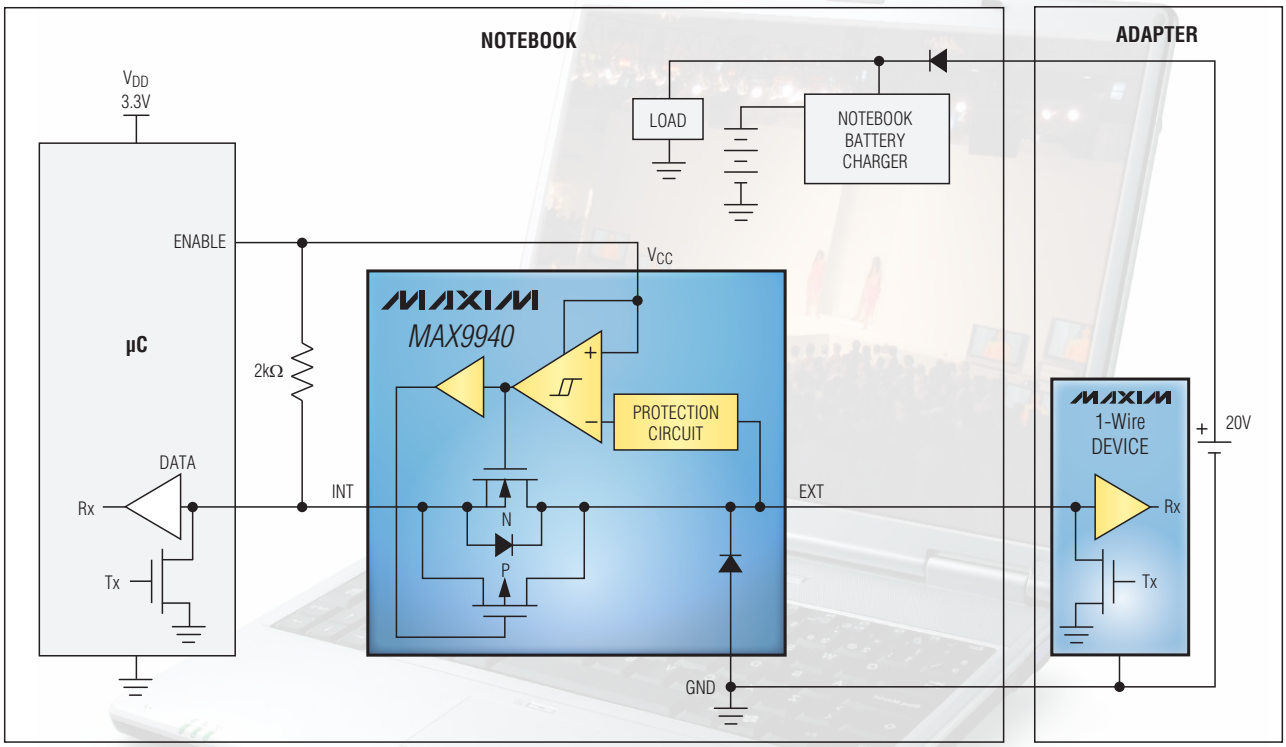
# Signal-line overvoltage protector ensures the safety and integrity of computing devices

## Protects low-voltage devices by using sensitive communication protocols

### MAX9940

The MAX9940 is a signal-line overvoltage protector for low-voltage digital communication ports. This device protects against high-voltage faults and ESD strikes. An ideal solution for protecting notebook microcontrollers, the MAX9940 works well with sensitive communication protocols, such as Maxim's 1-Wire® technology, that require more than the standard fault protection with large series resistors or large line capacitances.

- **A fully integrated, low-power overvoltage solution**
  - 28V protection on EXT protects against high-voltage shorts
  - Extended protection (±4kV IEC 61000-4 Contact Discharge on EXT) minimizes ESD concerns
  - Fast 60ns fault reaction time ensures safety of protected devices
  - Low 13µA quiescent current conserves power in battery-operated devices
  - Small, 2mm x 2mm, 5-pin SC70 package saves space in portable applications




*Signal-line overvoltage protector provides peace of mind.*

1-Wire is a registered trademark of Maxim Integrated Products, Inc.

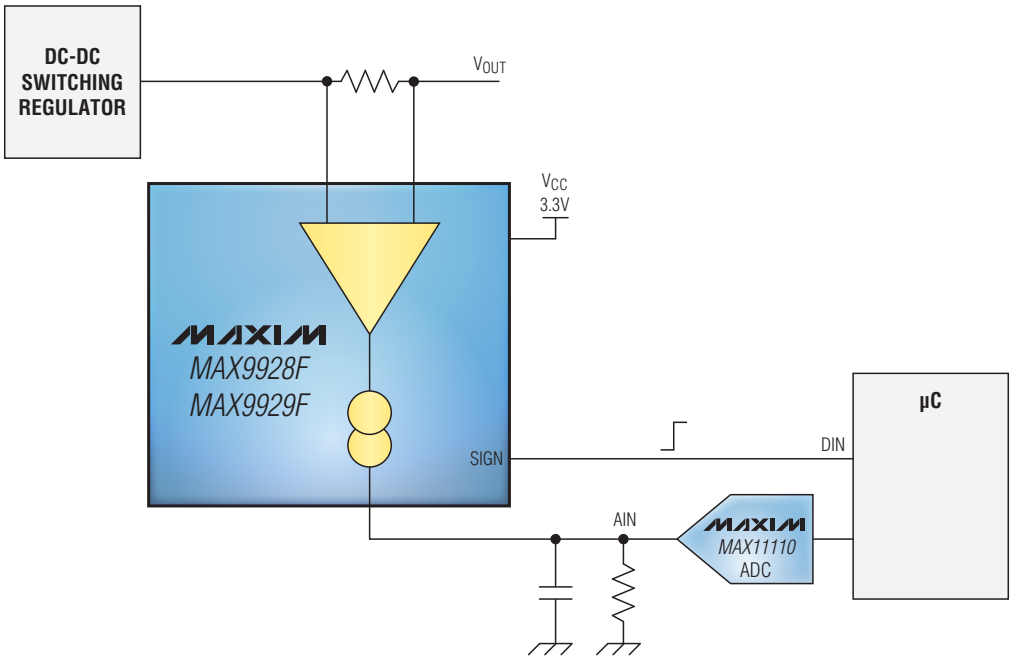
# True bidirectional sensing delivers high precision and unique versatility

## Current-sense amplifiers are ideal for monitoring charge and discharge currents

### MAX9928F/MAX9929F

The MAX9928F/MAX9929F low-cost, uni-/bidirectional, high-side current-sense amplifiers are ideal for monitoring battery charge and discharge currents in notebooks, cell phones, and other portable equipment. These devices feature a wide -0.1V to +28V input common-mode voltage range; low 20µA supply current with $V_{OS}$ less than 0.4mV; and gain accuracy of better than ±1.0%. A digital SIGN output indicates direction of current flow, so the user can utilize the full ADC input range for measuring both charging and discharging currents.

- **Precision performance under changing conditions**
  - Low 400µV (max) $V_{OS}$ over entire $V_{CM}$ range enables accurate measurement, even if rails are shorted to ground
- **Unique features facilitate application flexibility**
  - SIGN output enables true bidirectional sensing and allows full use of ADC dynamic range
  - Current output (MAX9928F) provides infinite gain granularity




*Current output (MAX9928F) provides immunity from ground-bounce by enabling local termination near the ADC.*

**To learn more about bidirectional current-sense amplifiers, go to:**
**www.maxim-ic.com/bidirectional-CSAs**

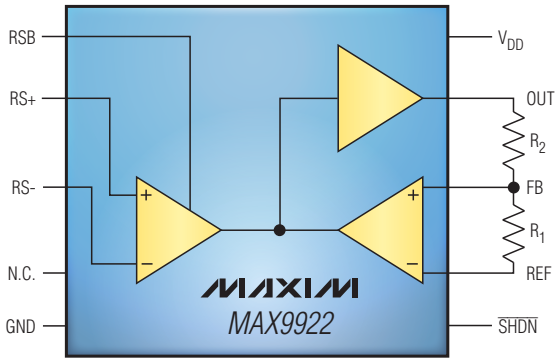
# High-performance current monitoring provides precise measurement for very small sense voltages

## Ultra-precise accuracy enables low current measurements in standby mode and system monitoring in active mode

### MAX9922/MAX9923

The MAX9922/MAX9923 ultra-precision, high-side current-sense amplifiers feature an ultra-low $V_{OS}$ of 10µV (max) and laser-trimmed gain accuracy of better than ±0.5%. The combination of low $V_{OS}$ and high-gain accuracy allows precise current measurements, even at very small sense voltages. The MAX9922/MAX9923 provide uni-/bidirectional operation. The MAX9922 has adjustable gain set with two external resistors. These devices deliver high performance for tablet and notebook applications.

- **High-precision measurement capability**
  - Ultra-low 10µV (max) $V_{OS}$ enables use of small sense resistor for minimally invasive current sensing
  - Gain error less than ±0.5%




*The MAX9922 enables precision monitoring of system power rails in tablets and notebooks.*

**To learn more about current-sense amplifiers, go to:**
**www.maxim-ic.com/CSAs**

## Overvoltage protector

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9940 | Signal-line overvoltage protector for low-voltage devices | 28V protection on EXT pin; extended ESD protection (±4kV IEC 61000-4 Contact Discharge on EXT); 13µA supply current; 2mm x 2mm SC70 | Protects low-voltage circuitry from high-voltage faults, thus improving reliability |

## Current-sense amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9928F/29F | Low-power, bidirectional current-sense amps | 20µA supply current; 1mm x 1.5mm UCSP; 400µV (max) $V_{OS}$; 28V common-mode range; current output (MAX9928F) | SIGN output enables use of full ADC range; current output allows adjustable gain |
| MAX9922/23 | Ultra-precision, high-side current-sense amps | 10µV (max) $V_{OS}$; 28V common-mode range | Ultra-low $V_{OS}$ enables precision monitoring with small sense resistor; current output allows adjustable gain |
| MAX9634 | Ultra-low-power current-sense amp | 1µA supply current; 1mm x 1mm UCSP; 250µV (max) $V_{OS}$; 28V common-mode range | Ultra-low supply current is ideal for “always-on” applications; most space-efficient, current-sensing solution |
| MAX9937 | General-purpose, low-power current-sense amp | 20µA supply current; 5-pin SC70; 28V common-mode range | Low-power, general-purpose solution minimizes BOM cost |

## Operational amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9617–20 | High-efficiency op amps with RRIO | 10µV (max) $V_{OS}$; 59µA supply current; 1.5MHz bandwidth; dual version in 8-pin SC70; shutdown mode (MAX9619) | Industry-leading combination of precision, low power, size, and bandwidth |
| MAX9636/37*/38* | Low-power, low-noise, CMOS-input, RRIO op amps | 38nV/$\sqrt{Hz}$ input-voltage noise; 50fA/$\sqrt{Hz}$ input-current noise; ultra-low 0.1pA bias current; 36µA supply current; 1.5MHz bandwidth; shutdown mode | Low noise and low $I_{BIAS}$ are ideal for sensitive sensor interface applications |
| MAX4230–34 | High-output-drive, RRIO op amps | 200mA output drive; 10MHz bandwidth; UCSP version available; shutdown mode | RF immunity helps avoid EMI issues; high output current is ideal for driver applications |
| MAX9910–13 | 200kHz, 4µA, RRIO op amps with shutdown | 200kHz bandwidth; 4µA supply current; shutdown mode | Optimized speed-to-power ratio minimizes current consumption |
| MAX9914–17 | 1MHz, 20µA, RRIO op amps with shutdown | 1MHz bandwidth; 20µA supply current; shutdown mode | Optimized speed-to-power ratio minimizes current consumption |
| MAX4470 | Ultra-low-power op amp with rail-to-rail outputs | 0.75µA supply current; 9kHz bandwidth | Low power extends battery life in portable applications |

## Comparators

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9060–64 | Ultra-small nanopower comparators | < 1µA supply current; 1mm x 1mm UCSP; versions with internal (0.2V) or external reference | Ultra-low supply current is ideal for “always-on” applications |
| MAX9025–28 | Nanopower, Beyond-the-Rails comparators | < 1µA supply current; 1mm x 1.5mm UCSP; versions with internal (1.2V) or external reference | Ultra-low supply current is ideal for "always-on" applications; accepts input voltages 200mV beyond the rails to provide application flexibility |

**www.maxim-ic.com/amps-comps**

*Future product—contact factory for availability.

# Industrial systems

## High-voltage signal conditioning and accurate sensor signal interfacing are essential for industrial process control and instrumentation equipment

The analog requirements for signal conditioning vary widely in industrial applications. For example, in weigh-scale applications, a low-noise and low-offset precision sensor interface improves system accuracy during signal amplification and conditioning. Also, programmable logic controllers (PLCs) require high accuracy and a low-drift analog front-end, while withstanding voltage transients and other harsh conditions before digital conversions occur.

Industrial systems operate in harsh environments under extreme temperatures and conditions. Maxim's product portfolio offers guaranteed precision signal conditioning and diagnostics at +125°C or across a wide voltage range.

### Current monitoring

Still common on factory floors, 4–20mA communication loops require precision current-sensing ICs to interpret and convert the current to a digital format. System power levels must also be monitored in order to acquire critically important information about the system's state of health and efficiency. Maxim offers small, highly integrated ICs capable of performing diagnostics, power-level measurements, and current-level monitoring to ensure safe system performance and easy management of maintenance.

### Op amps and comparators

Op amps and comparators have multiple roles in sensor interfaces. Some sensors are strain gauges measuring force, load, or pressure. Other sensors measure temperature. In all cases, op amps are used for precise amplification and filtering before digital conversion. Comparators are used for voltage detection and system diagnostics. A sensor short or open can be detected with one or more comparators, making it easy to notify the system microcontroller of a maintenance issue. Maxim offers an extensive line of autozeroing op amps that provide stability over time and temperature, as well as small form factor comparators used in diagnostics and monitoring.

# Maintain high accuracy over time and temperature with ultra-low-power, zero-drift precision op amps

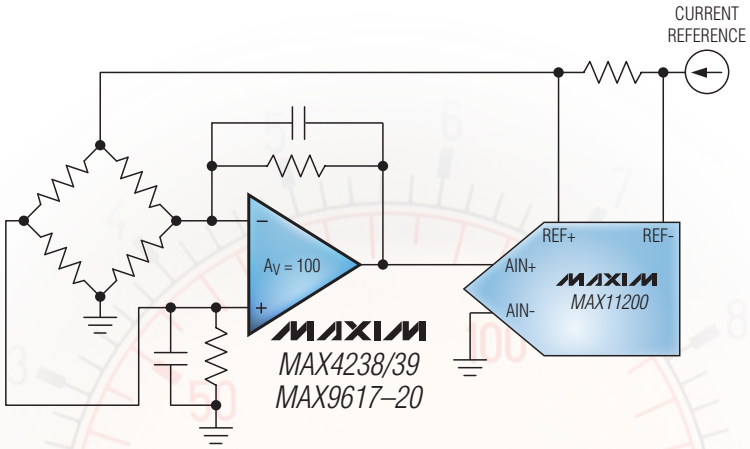
## MAX9617–MAX9620

The MAX9617–MAX9620 are low-power, zero-drift operational amplifiers available in space-saving SC70 packages. They provide 1.5MHz gain bandwidth (GBW), only 59µA supply current, and 10µV (max) zero-drift input $V_{OS}$ over time and temperature.

## MAX4238/MAX4239

The MAX4238/MAX4239 are low-noise, low-drift, ultra-high-precision amplifiers. Using patented autocorrelating zeroing techniques*, they offer near-zero DC offset and drift. This method constantly measures and compensates the input offset, thereby eliminating drift over time and temperature and the effect of 1/f noise.

- **Maintain system calibration and accuracy over time and temperature**
  - Autozero technology reduces voltage-offset temperature coefficient ($TCV_{OS}$) to 10nV/°C and $V_{OS}$ to only 2.5µV (max) at +85°C
- **Improve system accuracy and resolution**
  - Low input-voltage noise
  - No 1/f component ensures low-distortion signal conditioning below 0.1Hz with 30nV/√Hz input-voltage noise density




*The MAX4238/MAX4239 and MAX9617–MAX9620 op amps are ideal for driving ADCs.*

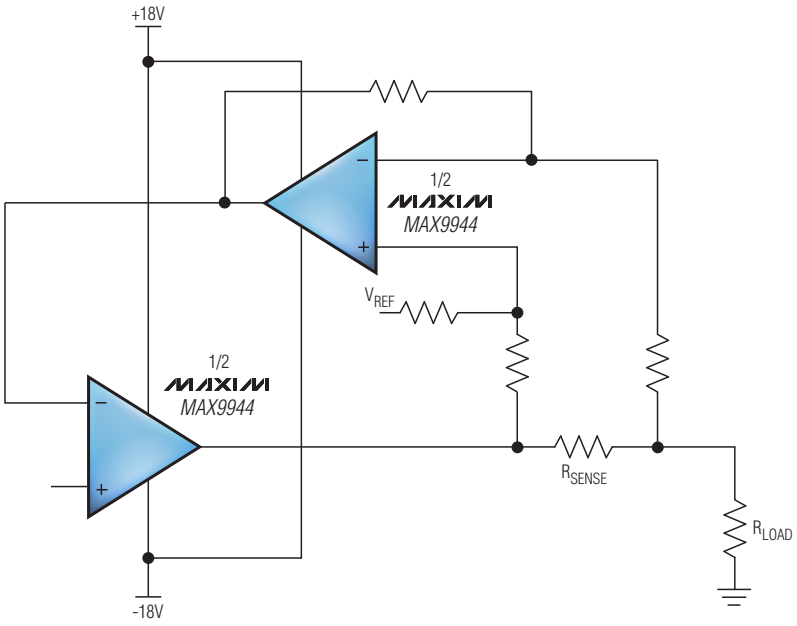
*U.S. Patent #6,734,723.

# High-precision output conditioners and drivers improve system accuracy for high-voltage applications in harsh environments

## MAX9943/MAX9944

The MAX9943/MAX9944 are high-voltage amplifiers (6V to 38V) that offer precision (100µV $V_{OS}$), low drift (0.4µV/°C), and low power consumption (550µA). Specified over the -40°C to +125°C automotive temperature range, these devices are ideal for sensor signal conditioning, high-performance industrial instrumentation, and loop-powered systems (e.g., 4–20mA transmitters).

- **Easily drive 24V 4–20mA lines throughout factory floors**
  - – High 6V to 38V supply-voltage operation and high 25mA output-current drive exceed current-mode communication requirements




*The MAX9944 accurately drives loads and is stable with up to a 1nF capacitive load.*

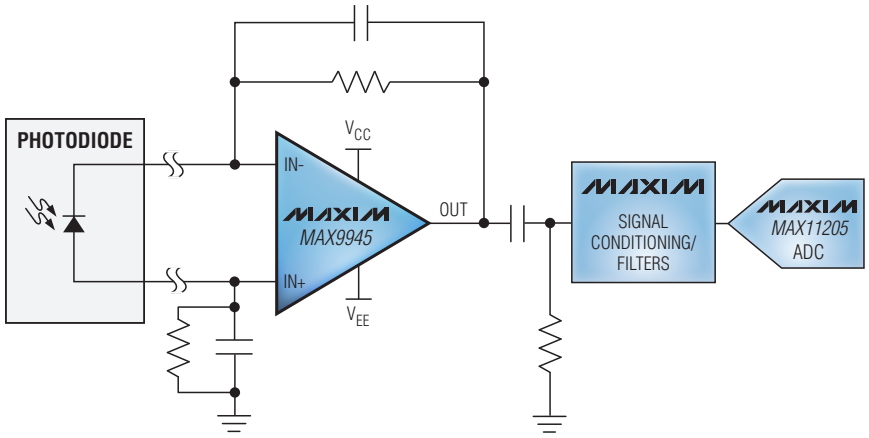
# Maximize system accuracy in photodiode and high-ohmic sensor applications

## 38V, MOS-input op amp offers excellent combination of low noise and low power

### MAX9945

The MAX9945 operational amplifier features an excellent combination of low operating power (400µA) and low input-voltage noise (2µ$V_{P-P}$). Due to MOS inputs, this op amp features low input-bias currents and low input-current noise.

- **Improves system's signal-to-noise ratio (SNR) for more accurate measurements**
  - 50fA low input-bias current
  - 1fA/√Hz low input-current noise
  - 15nV/√Hz low voltage-noise density
- **High-voltage robust design simplifies mixed-voltage designs**
  - 4.75V to 38V single-supply voltage range
  - ±2.35V to ±19V dual-supply voltage range
  - Rail-to-rail output-voltage swing




*Highly accurate light-sensor interface features the MAX9945 op amp.*

## Operational amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9632* | 36V, low-noise, precision, single op amp | Wide 4.5V to 38V supply range; low 0.94nV/√Hz noise; low THD of -130dB | High-fidelity signal conditioning enables easy interfacing with precision, 24-bit sigma-delta ADCs |
| MAX9633* | 36V, low-noise, precision, dual op amp | Wide 4.5V to 38V supply range; low 3nV/√Hz noise; fast 750ns settling time | Low noise and fast response help accurately drive 16-bit ADCs |
| MAX9943/44 | 38V, precision, single and dual op amps | Wide 6V to 38V supply range; low 100µV (max) input $V_{OS}$; drive 1nF loads | Enable versatility and ease of use when designing voltage translators and sensor interfaces |
| MAX9945 | 38V, CMOS-input, precision op amp | Wide 4.75V to 38V supply range; low 50fA input-bias current; rail-to-rail output swing | Eases high-voltage interfacing with ultra-high-ohmic sensors |
| MAX410/12/14 | 28MHz, 10V, low-noise, precision op amps | 2.4nV/√Hz; 250µV offset; 28MHz GBW | Provide high-accuracy signal conditioning across a wide frequency range or at high gain |
| MAX4238/39 | Industry's lowest offset, low-noise op amps | 2µV (max) $V_{OS}$; 25nV/√Hz; rail-to-rail output; 6.5MHz GBW; no 1/f input-noise component | Continuous precision over time and temperature—maintains accuracy without calibration |
| MAX9939 | SPI™-programmable gain amp with on-demand calibration and differential in/out configuration | Input supports negative voltages; wide range of gain configurations; input error-nulling feature | Calibration on-demand improves system accuracy, minimizes harsh environmental noise |
| MAX9617–20 | High-efficiency op amps with RRIO | 10µV (max) $V_{OS}$; 59µA supply current; 1.5MHz bandwidth; dual version in 8-pin SC70; shutdown mode (MAX9619) | Autozero technology calibrates over time and temperature, thus reducing coefficient errors in the system |

## Current-sense amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9918/19/20 | Precision high-side, uni-/bidirectional current-sense amps | +75V down to -20V voltage monitoring; voltage output | Robust design handles unwanted voltage transients down to -20V and up to +75V |
| MAX4080/81 | High-side, uni-/bidirectional current-sense amps | 4.5V to 76V input-voltage range | Robust design handles unwanted voltage transients down to -4.5V and up to +75V |
| MAX9928F/29F | Low-power, bidirectional current-sense amps | 20µA supply current; 1mm x 1.5mm UCSP; 400µV (max) $V_{OS}$; 28V common-mode range; current output (MAX9928F) | SIGN output indicator simplifies bidirectional sensing; simple, settable gain for application flexibility |
| MAX9937 | General-purpose, low-power current-sense amp | 20µA supply current; 5-pin SC70; 28V common-mode range; reverse-battery protection; EMI-suppression circuitry | System robustness provides improved reliability |
| MAX4211 | High-side power and current monitor with two comparators and reference | Real-time system power and current measurement with diagnostics or system fault detection | Simplifies monitoring of system's state of health and performance; prevents current runaway |

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SPI is a trademark of Motorola, Inc.
*Future product—contact factory for availability.

# Telecom products

## Antenna positioning, power-level management, and accurate sensor signal interfacing are essential tasks for telecom applications

Telecom applications, such as base stations, are made up of various subsystems, from antenna positioning to power-level management. Telecom companies need to accurately measure position and power levels to ensure that maximum coverage is provided to the mobile user. Maxim provides transceivers for antenna positioning, current-sensing ICs for power management, and signal-conditioning solutions for next-generation systems.

### Application-specific telecom ICs

Maxim recently introduced the MAX9947, the industry's first AISG-compliant, fully integrated transceiver for base stations and tower equipment. This device helps simplify designs, improves performance, and increases system reliability for both the base station and tower. It provides a two-chip solution that facilitates RS-485 bus arbitration in tower-mounted equipment without requiring a microcontroller, thus saving cost and space.

### Current monitoring

Base stations often have battery-stack power sources, as well as high voltages up to 48V. Current-measurement schemes, commonly involving power-consumption calculations, are needed to ensure that these systems are functioning at their optimum levels. Maxim's current-sense amplifiers are designed to monitor and manage real-time true power levels, current consumption, and battery performance without interruption.

### Op amps and comparators

Op amps and comparators perform numerous functions in simple to highly complex communication systems. They drive ADCs, filter signal sources, and monitor thermal and current levels so that current runaway does not occur. Maxim provides a wide selection of low-power and high-performance 5V op amps, 30V op amps, and a broad range of single-/dual-channel comparators with and without voltage references to meet the most demanding telecom challenges.

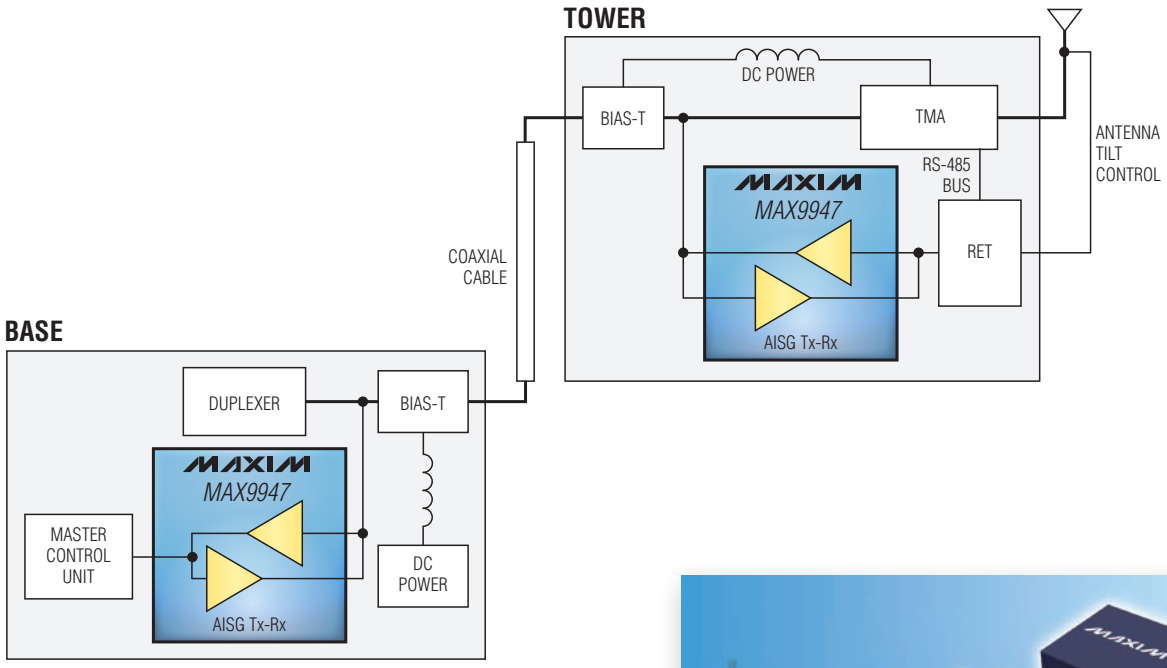
# AISG-compliant, fully integrated transceiver is 100x smaller than discrete designs

## High integration simplifies solutions for base stations and tower equipment

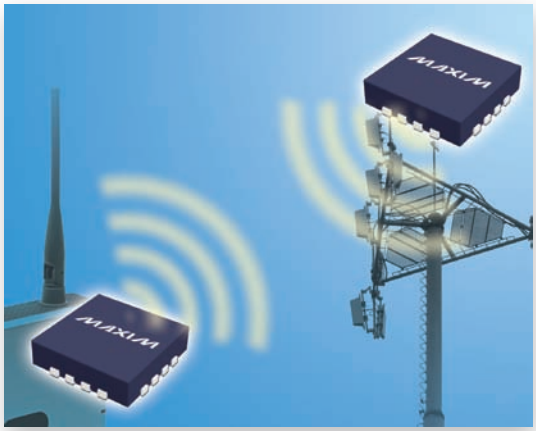
### MAX9947

This single-chip solution integrates a transmitter, receiver, and active filters into a 3mm x 3mm TQFN package that is 100x smaller than discrete solutions. Additionally, the transceiver provides an autodirection output to facilitate RS-485 bus arbitration in tower-mounted equipment without requiring a microcontroller.

- **High integration eases the design burden, lowers costs, and speeds time to market**
  - Single-chip solution with on-board transmitter, receiver, and active filters
- **Greatly simplifies design**
  - Eliminates need for microcontroller traditionally required in tower-mounted equipment
- **100x smaller than discrete solutions**
  - 3mm x 3mm TQFN package




*The MAX9947 is ideal for AISG-compliant telecom equipment.*



# 10:1 current monitors are optimized for sensing six decades of current

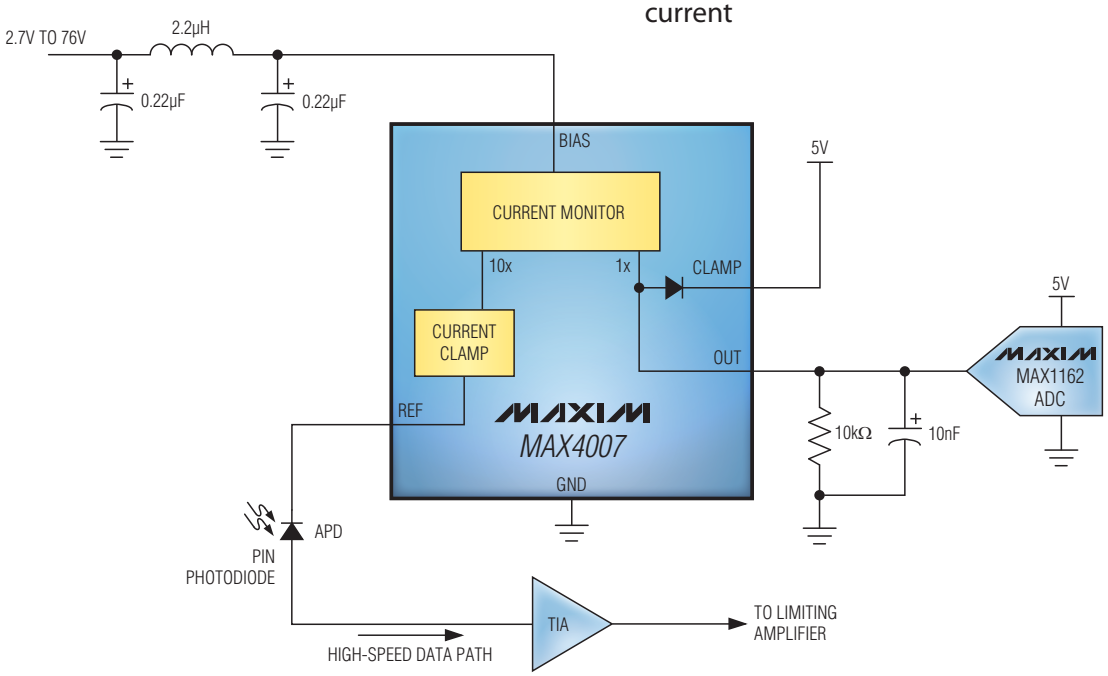
## High-voltage, high-side current monitors sense currents from 10nA to 10mA

### MAX4007/MAX4008

The MAX4007/MAX4008 precision, high-side, high-voltage (76V) current monitors are specifically designed for monitoring system current in industrial and communications applications.

These current monitors have six decades of dynamic range and monitor reference currents of 250nA to 2.5mA with better than ±5% accuracy.

- **Ease the design burden, reduce costs, and simplify system designs**
  - Single-chip solutions with integrated current monitor
- **Provide design flexibility for the end user**
  - Current-to-voltage conversion and current-to-current conversion options
- **Increase the robustness of the end application**
  - Wide dynamic voltage range over six decades of current




*Typical application circuit for high-voltage APD current monitoring in telecom systems.*

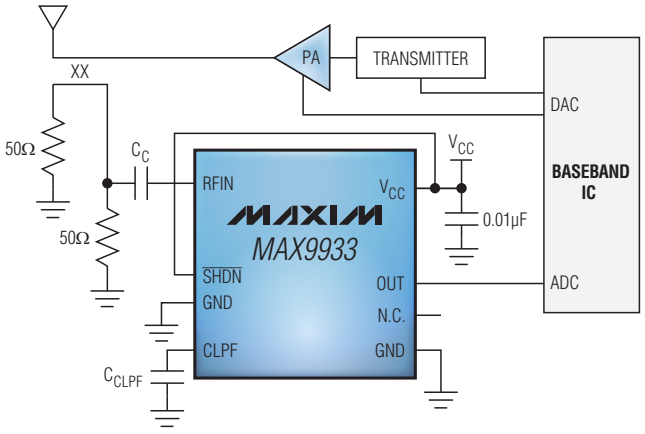
# RF-detecting controllers simplify control-loop design of PAs and TIAs

## Three input-voltage ranges eliminate need for external attenuators

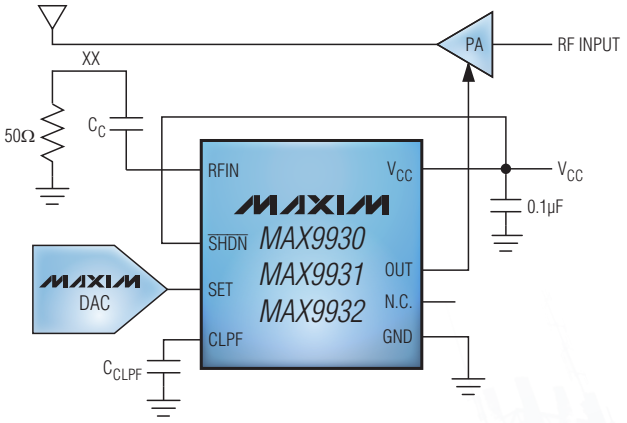
### MAX9930–MAX9933

The MAX9930–MAX9933 low-cost, low-power, logarithmic amplifiers control RF power amplifiers (PAs) and transimpedance amplifiers (TIAs); they also detect RF power levels. With three different input-voltage ranges, these devices eliminate the need for external attenuators and simplify amplifier control-loop design.

- **Logarithmic amplifier design provides a much wider, more accurate measurement range**
- **Simplify system design**
  - Three signal-range options, each providing 45dB of dynamic range
- **Reduce component count**
  - No external attenuators required to attenuate or condition the input signal




*Typical application circuit for the RF-detecting controller.*




*Circuit shows the RF-detecting controllers in control mode.*

## AISG transceiver

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9947 | Fully integrated transceiver for base stations and tower antenna positioning | AISG compliant; fully integrated transceiver | High integration eases design burden, reduces costs, and speeds time to market |

## Current-sense amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX4007/08 | High-accuracy, 76V, high-side current monitors | Senses six decades of current from 10nA to 10mA | High-voltage design increases product robustness |
| MAX9918/19/20 | Precision, high-side, uni-/bidirectional current-sense amps | +75V down to -20V voltage monitoring; voltage output | Robust design handles unwanted voltage transients down to -20V and up to +75V |
| MAX4080/81 | High-side, uni-/bidirectional current-sense amps | 4.5V to 76V input-voltage range | Robust design handles unwanted voltage transients down to -4.5V and up to +75V |
| MAX9928F/29F | Low-power, bidirectional current-sense amps | 20µA supply current; 1mm x 1.5mm UCSP; 400µV (max) $V_{OS}$; 28V common-mode range; current output (MAX9928F) | SIGN output indicator simplifies bidirectional sensing; simple, settable gain for application flexibility |
| MAX9937 | General-purpose, low-power current-sense amp | 20µA supply current; 5-pin SC70; -20V to +40V reverse-bias protection; EMI-suppression circuitry | System robustness improves reliability |
| MAX4211 | High-side power and current monitor with two comparators and reference | Real-time system power and current measurement with diagnostic or system fault detection | Simplifies monitoring of system's state of health and performance; prevents current runaway |

## Operational amplifiers

| Part | Description | Features | Benefits |
|---|---|---|---|
| MAX9930–33 | 2MHz to 1.6GHz, 45dB, RF-detecting controllers and RF detector | Dynamic range of 45dB with an accuracy of ±1dB | Three input-voltage ranges eliminate the need for external attenuation; logarithmic amplifier design provides wide, accurate measurement range and reduces component count |
| MAX9943/44 | 38V, precision single and dual op amps | Wide 6V to 38V supply range; low 100µV (max) input $V_{OS}$; drives 1nF loads | Enable versatility and ease of use when designing voltage translators and sensor interfaces |
| MAX9945 | 38V, CMOS-input, precision op amp | Wide 4.75V to 38V supply range; low 50fA input bias current; rail-to-rail output swing | Eases high-voltage interfacing with ultra-high-ohmic sensors |
| MAX9650 | High-output-current op amp | 1.3A peak current drive | Provides high-accuracy signal conditioning for high current drive without external resistors |
| MAX4475–78 | Low-noise/distortion (4.5nV/$\sqrt{Hz}$), rail-to-rail output op amps | Low 0.0002% THD+N (1kΩ load); single, dual, and quad versions | High fidelity for precision ADC conversion |
| MAX9617–20 | High-efficiency op amps with RRIO | 10µV (max) $V_{OS}$; 59µA supply current; 1.5MHz GBW; dual version in 8-pin SC70; shutdown mode (MAX9619) | Autozero technology calibrates over time and temperature, thus reducing coefficient errors in the system |

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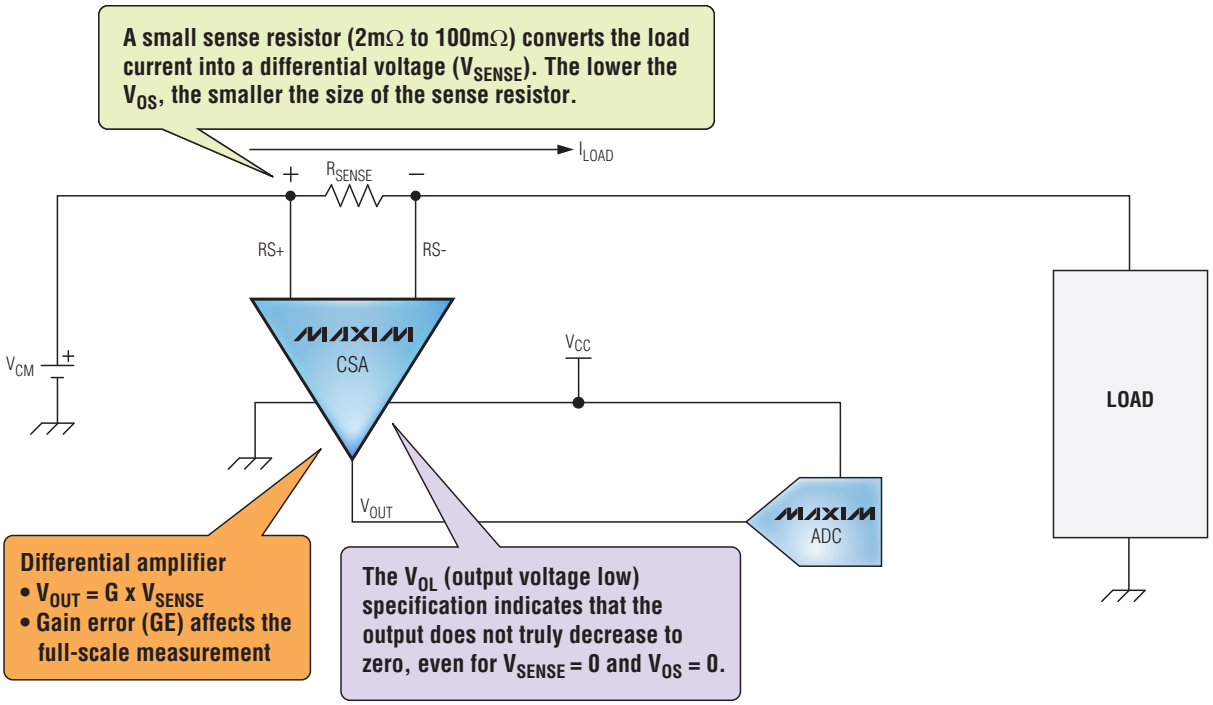
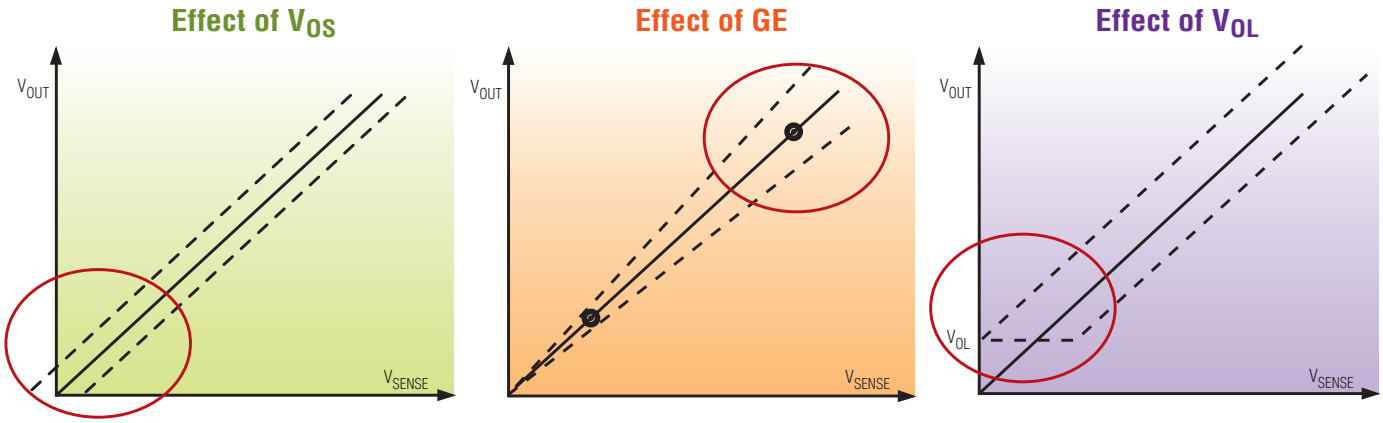
# How to obtain the best performance from current-sense amps

## Current-sense amp errors can affect overall performance if not properly taken into account



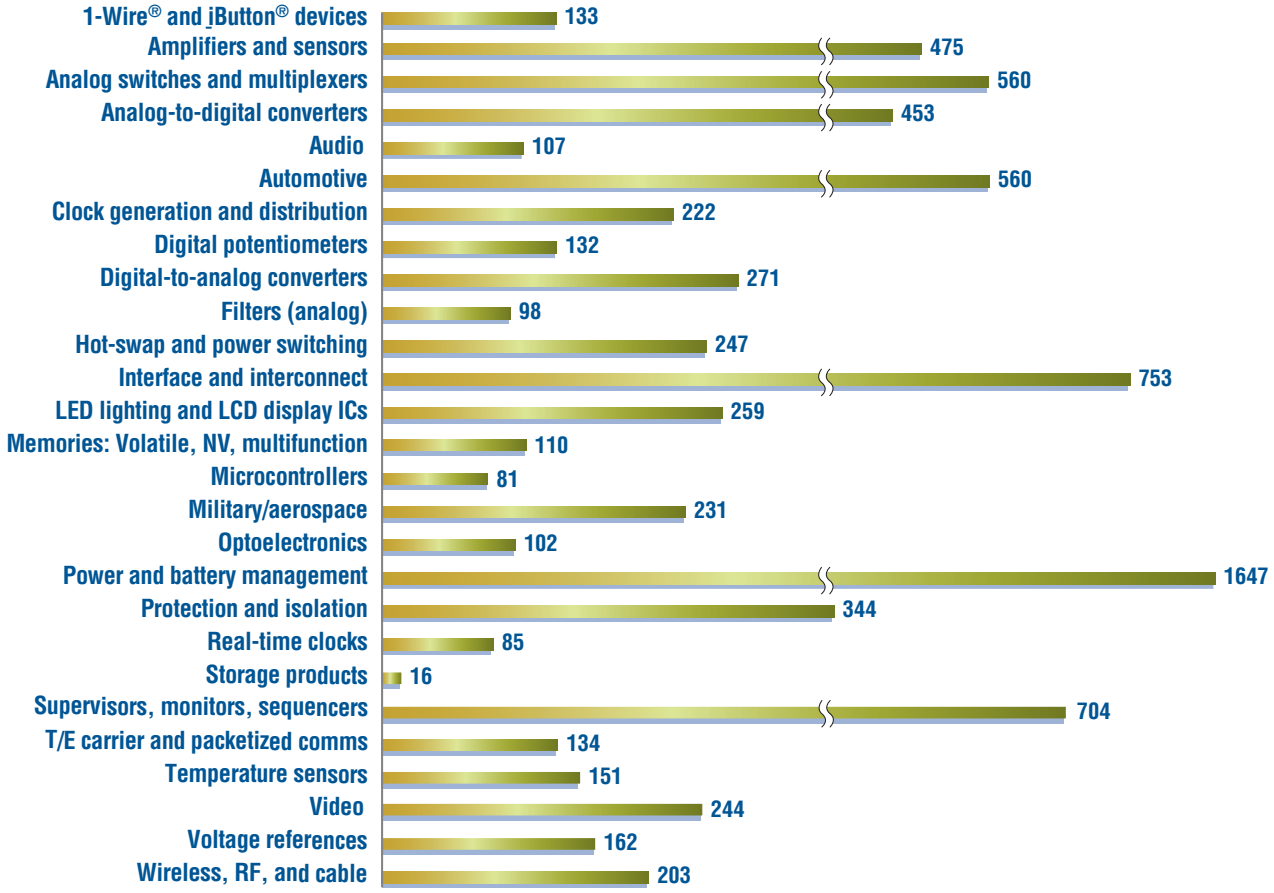

$V_{OS}$ affects the measurement of the low current range. It is important to have low $V_{OS}$, so as to reduce the size of the sense resistor. Low $V_{OS}$ also increases the dynamic range of current measurement. Gain error affects this measurement in the higher current ranges and at full scale. Sense resistor tolerance affects the total error of the measurement, and total error is given by the combination of $V_{OS}$, GE, and $R_{SENSE}$ tolerance as per the equations below:

$$V_{OUT} = (G \pm |GE|) \times (V_{SENSE} \pm |V_{OS}|) \qquad V_{SENSE} = I_{LOAD} \times R_{SENSE}$$

# Yes, we make that...

Maxim has one of the broadest and deepest analog and mixed-signal portfolios, with over 6300 ICs in 28 categories. We average more than one product introduction per day! For over 25 years, we have delivered innovative engineering solutions that add value to our customers' products.

## *Over 6300 ICs in 28 product categories*

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