

2nd Edition

PROCESS CONTROL

Solutions Guide

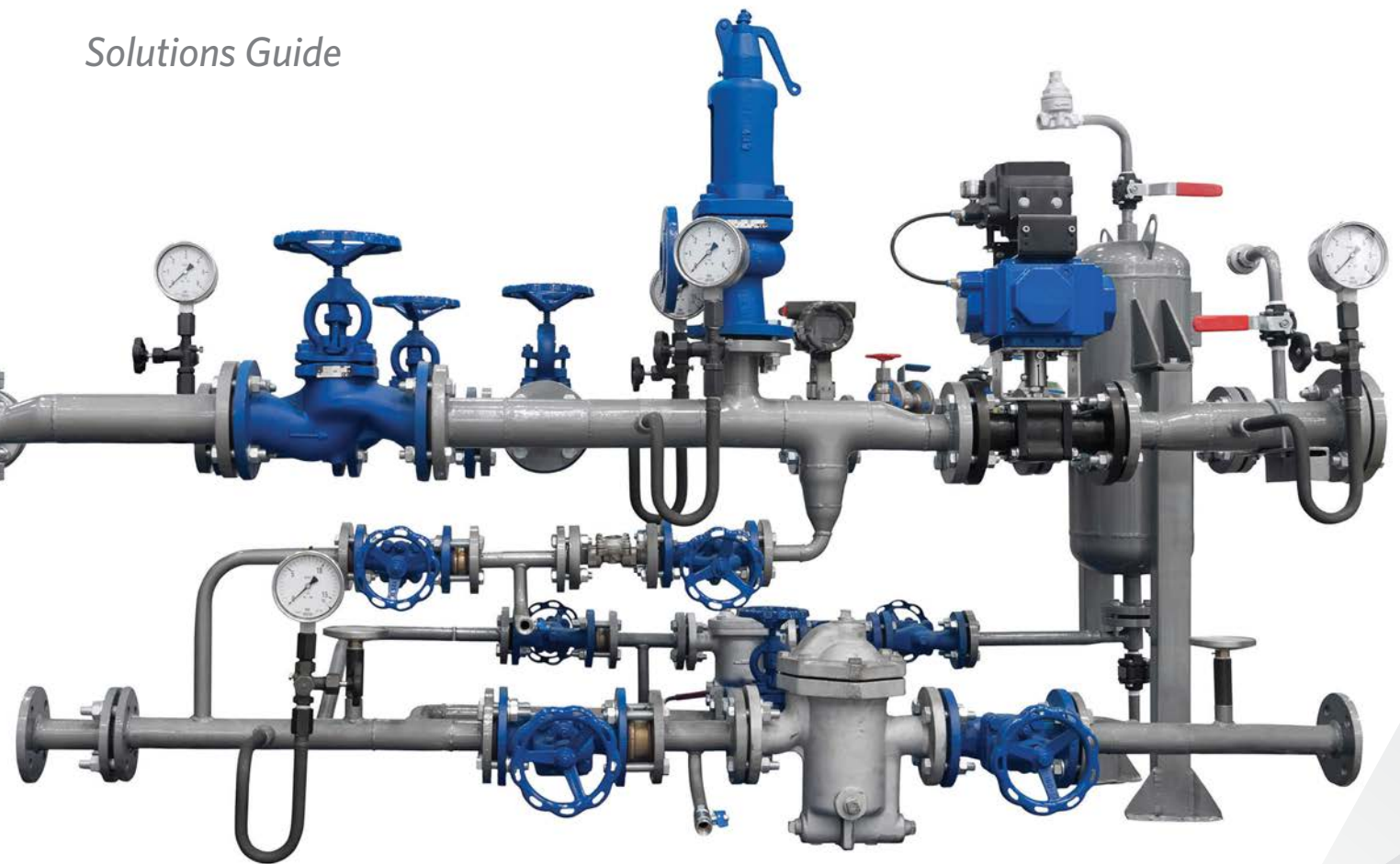


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Maxim Integrated Means Great Solutions and Support

A Message from the Senior Vice President, Industrial and Medical Solutions Group

Thank you for considering Maxim Integrated as your analog IC supplier. Our goal is simple: to be your supplier of choice. This handbook highlights our innovative solution and support capabilities for the industrial market.

At Maxim, we pride ourselves in first understanding our customers' needs, then developing the appropriate solutions to meet them. As a result, we are able to provide application-specific functionality, while still maintaining the flexibility needed for custom designs.

Leveraging our 30 years of experience, we offer exceptional products that deliver better performance, use less power, and provide the accuracy and reliability necessary for your industrial applications.

Our product portfolio addresses all aspects of sensor signal chains, control signal chains, and communications interfaces from conditioning to capture, transmission to timing, and power to precision.

In addition to our innovative solutions, we also provide great customer support, including superior reference designs, and technical service.

Thank you again for considering Maxim. We look forward to working with you.

Sincerely,

A handwritten signature in black ink that reads "Chris". The signature is fluid and cursive, with a long horizontal stroke at the end.

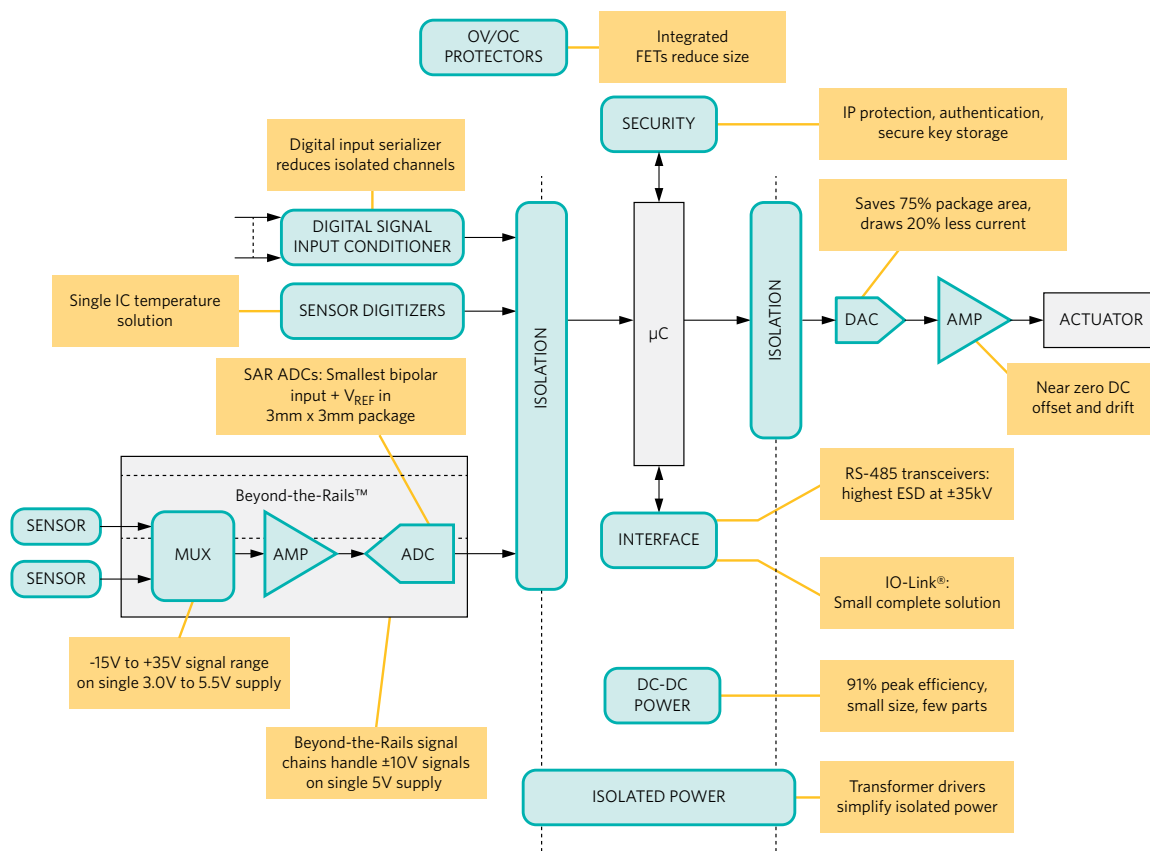
Chris Neil

Senior Vice President, Industrial and Medical Solutions Group

Introduction

Process control is primarily enabled by the PLC (programmable logic controller) or the PAC (programmable automation controller). Today the controllers are quite similar, but both began with slightly different roots. The modern PLC is the result of technology advancement from the control realm, whereas the modern PAC is the result of technology advancement from the data communications realm. Now PLCs have communications capability and PACs have control capability, so the differences are blurred. We will use the term "PLC" to refer to both controllers. The PLC's block diagram can be simplified to the one shown below. In larger, modular PLCs, I/O modules exist as plug-in cards with their own microcontroller per card and a backplane connection to a high-speed bus that runs between each I/O module and a plug-in CPU module. Additionally, there is usually a power-supply module and a communications module. For simplicity, we have not broken out this detail.

All the solutions presented in this guide are intended for use in industrial process control, HVAC and building automation, motor control, and other industrial applications.



Generic PLC block diagram. Maxim offers solutions for most of the blocks in the PLC, indicated by the teal color. Our microcontroller solutions are not typically suited for the high processing power required in the PLC. More detailed block diagrams are available on our website at: www.maximintegrated.com/PLC.

Industrial Power Supplies

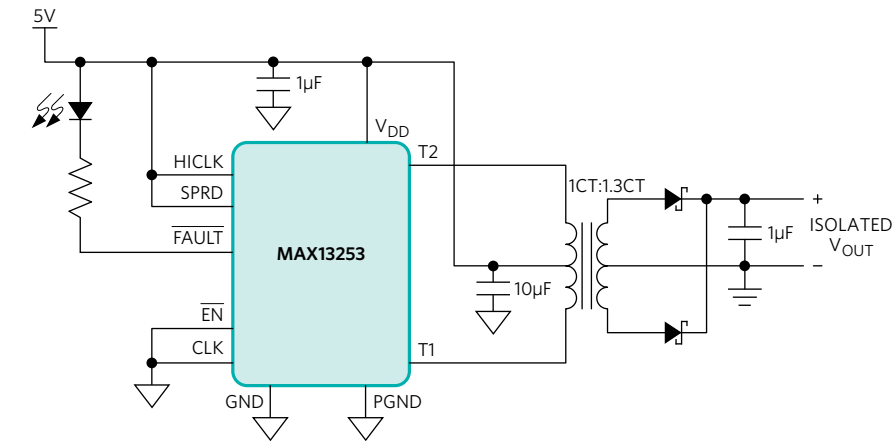
Isolated Power Supplies

Isolated power is a common system requirement in all types of PLC I/O modules. Depending on how well the nonisolated input to the isolated converter is regulated, users can choose different options. If the input to the isolation converter is fairly well regulated, a simplification is possible using Maxim’s transformer drivers. They run open loop at a fixed 50% duty cycle to drive the isolation transformer. With a regulated input, simple point of load LDOs are all that are needed to provide a high-efficiency, tightly regulated final supply. This approach enables simpler designs with many protections and performance enhancement features integrated.

Maxim’s family of transformer drivers accept wide DC input voltage ranges from 3V to 5V and 8V to 36V.

MAX13253 Transformer Driver

Our latest transformer driver, [MAX13253](#), is a 1A driver for push-pull configurations and offers spread spectrum switching to reduce EMI/RFI. Protection features include loss of clock watchdog, overcurrent protection, thermal shutdown, and undervoltage lockout.



Key Features

- Low R_{ON} 300m Ω (max) at 4.5V
- Up to 90% efficiency
- Internal or external clock source
- Optional spread-spectrum oscillation
- -40°C to +125°C operating temperature range
- Small 10-pin TDFN package (3mm x 3mm)

Selector Table: Transformer Drivers for Isolated Power Supplies

Part	Description	Features	Benefits
MAX256	Low-voltage transformer driver for isolated power	3W output power, full bridge, integrated protection	Simple open-loop circuit speeds isolated power-supply design.
MAX13253	Low-voltage transformer driver with spread spectrum	5W output power, 3V to 5V supply, current limiting, 90% efficiency, spread spectrum	Simple open-loop circuit for isolated power eases EMI management with spread-spectrum switching.
MAX13256	36V transformer driver for isolated power	10W output, 8V to 36V supply, full bridge, 90% efficiency, integrated protection	Simple open-loop circuit speeds isolated power-supply designs with higher voltage and higher power requirements.

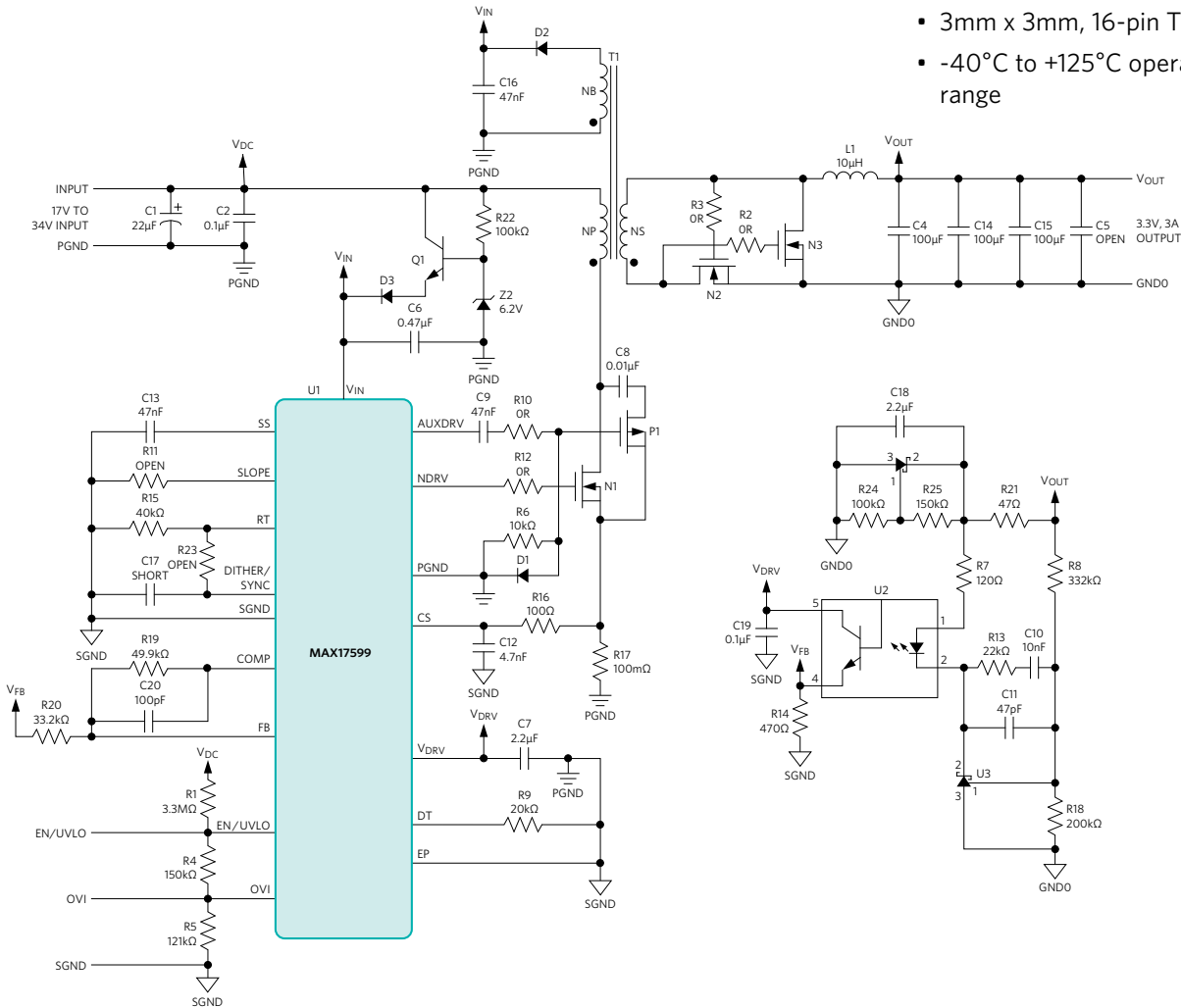
Isolated Power Supplies (cont.)

MAX17599 Active-Clamp PWM Controller

The MAX17599 supports active-clamp, peak-current mode, forward converter topologies. Operating over 100kHz to 1MHz, this device provides frequency dithering spread-spectrum to reduce EMI. Protection features include under-voltage lockout, overvoltage protection, short-circuit protection, and more.

Key Features

- 4.5V to 36V input
- Spread spectrum and frequency synchronization
- Adjustable soft-start and slope compensation
- 3mm x 3mm, 16-pin TQFN package
- -40°C to +125°C operating temperature range



Selector Table: PWM Controllers for Isolated Power Supplies

Part	Description	Features	Benefits
MAX17497B	4.5V to 36V flyback converter with integrated 12VIN/3.3VOUT buck regulator	10W+ output power, 4.5V to 36V supply, 250/500kHz, integrated protection, 60V FET	High frequency for tiny magnetics, regulates both positive/negative outputs, and has optional spread spectrum.
MAX17498B/C	4.5V to 36V flyback converters	10W+ output power, 4.5V to 36V supply, 250/500kHz, integrated protection, 60V FET	High frequency for tiny magnetics, regulate both positive/negative outputs, and have optional spread spectrum.
MAX17596	4.5V to 36V flyback converter	10W+ output, 4.5V to 36V supply, 100kHz to 1MHz, integrated protection	Spread spectrum mitigates EMI, optimized magnetics/filters.
MAX17599	4.5V to 36V active clamp and forward converter	100W+ output, 100kHz to 1MHz operation, 92%+ efficiency, integrated protection	Spread spectrum mitigates EMI, optimized magnetics/filters.

Isolated Power-Supply Reference Designs

Proven isolated power-supply reference designs speed your design process. Maxim is expanding our portfolio of bench-tested subsystem reference designs. The selector table offers available designs for isolated industrial power-supply applications.

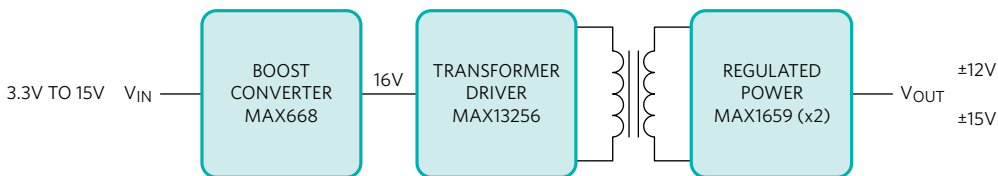
The Oceanside design ([MAXREFDES9#](#)) uses a step-up controller ([MAX668](#)), a 36V H-bridge transformer driver ([MAX13256](#)), and a pair of low dropout (LDO) linear regulators ([MAX1659](#) x2) to create a $\pm 15V$ ($\pm 12V$) output isolated power supply from a wide range of input voltages. If the input to the isolated converter is not regulated tightly, users would require a tightly regulated PWM controller. Maxim provides PWM controllers for isolated applications supporting 4.5V to 36V input in flyback and active-clamp topologies.

Key Features

- Isolated power
- $\pm 15V$ ($\pm 12V$) outputs
- Pmod™-compatible form factor



The Oceanside subsystem design board.



The Oceanside subsystem design block diagram.

Selector Table: Reference Designs for Isolated Industrial Power Supplies

Design	Input	Output	Description	Features	Benefits
Lakewood (MAXREFDES7#)	3.3V	$\pm 12V$ ($\pm 15V$)	Isolated power supply using H-bridge transformer driver and pair of LDOs	1500V _{RMS} isolated power, $\pm 12V$ at 90mA, $\pm 15V$ at 40mA output, Pmod-compatible form factor	Simple isolated power, reduced size, quick prototyping.
Oceanside (MAXREFDES9#)	3.3V to 15V	$\pm 15V$ ($\pm 12V$)	Isolated power supply using step-up controller, H-bridge transformer driver, and pair of LDOs	5000V _{RMS} Isolated power, $\pm 15V$ at 90mA, $\pm 12V$ at 100mA output, Pmod-compatible form factor	Simple isolated power, reduced size, quick prototyping.
Riverside (MAXREFDES8#)	3.3V	12V (15V)	Isolated power supply using H-bridge transformer driver and an LDO	1500V _{RMS} isolated power, 12V at 165mA, 15V at 60mA output, Pmod-compatible form factor	Simple isolated power, reduced size, quick prototyping.

High-Voltage Buck Regulators

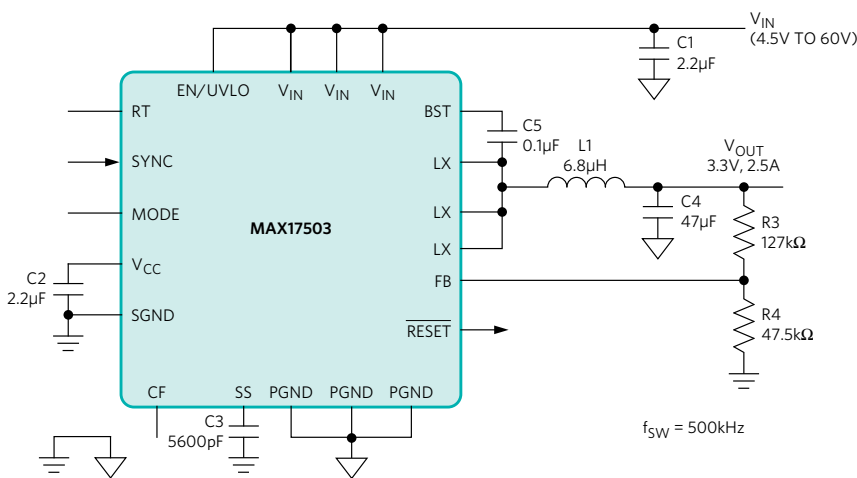
MAX17503 Synchronous Step-Down Converter

Maxim's latest industrial synchronously rectified buck regulators offer wide input voltage range and integrated FETs for a small size, low-component-count, high-efficiency solution. Peak efficiency of > 90% can be achieved as a result of synchronous rectification with internal high-side and low-side MOSFETs.

The MAX17503 2.5A buck regulator is a good example of this family of parts. We are expanding our portfolio of wide input voltage solutions to include lower and higher output current capabilities from 10s of mA to 10s of Amperes.

Key Features

- Operates from a 4.5V to 60V input supply
- Adjustable output voltage from 0.9V to $(0.92)V_{IN}$
- 200kHz to 2.2MHz internally compensated across output voltage and switching frequency
- -40°C to +125°C operating temperature range
- 4mm x 4mm TQFN package



Synchronously rectified 60V_{IN} DC-DC step-down converter.

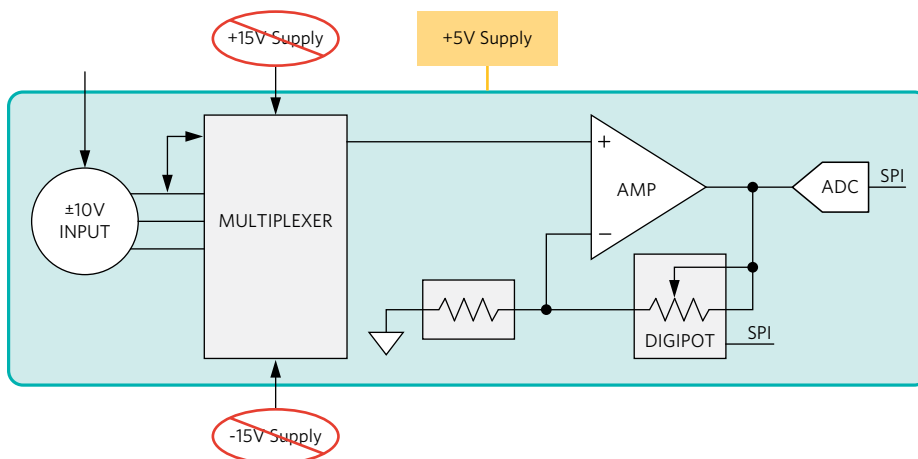
Selector Table: Industrial Regulators

Part	Description	Features	Benefits
MAX17503	60V, 2.5A high-efficiency synchronous step-down DC-DC converter	4.5V to 60V input range, synchronous rectification with internal MOSFETs, internal compensation	Address 24V nominal V_{IN} with ample tolerance, > 90% peak efficiency, as low as five external components, small size.
MAX17502	60V, 1A, high-efficiency synchronous step-down DC-DC converter	4.5V to 60V input range, synchronous rectification with internal MOSFETs, internal compensation	Address 24V nominal V_{IN} with ample tolerance, > 90% peak efficiency, as low as five external components, small size.
MAX17501	60V, 500mA, high-efficiency synchronous step-down DC-DC converter	4.5V to 60V input range, internal synchronous MOSFETs, internal compensation	Address 24V nominal V_{IN} with ample tolerance, > 90% peak efficiency, as low as five external components, small size.
MAX15062A/B	60V, 300mA, high-efficiency synchronous step-down DC-DC converters	4.5V to 60V input range, internal synchronous MOSFETs, internal compensation PFM/PWM mode	Address 24V nominal V_{IN} with ample tolerance, > 90% peak efficiency, as low as four external components, small size.

Beyond-the-Rails Technology

Maxim's Beyond-the-Rails technology simplifies design challenges inherent in handling industrial signaling levels, often $\pm 10\text{V}$ or more. Beyond-the-Rails parts can handle signals that go beyond their power-supply rails—both above and below. This can reduce the complexity of designs by eliminating power supplies needed for just the front end, before attenuation is possible. Additional benefits of Beyond-the-Rails include likely higher overall efficiency, fewer parts, simpler layout with fewer power-supply rails to route, and smaller total solution size—all leading to cost savings. Maxim's Beyond-the-Rails technology includes analog switches/muxes, digipots, and ADCs.

Bipolar inputs need only a single supply!

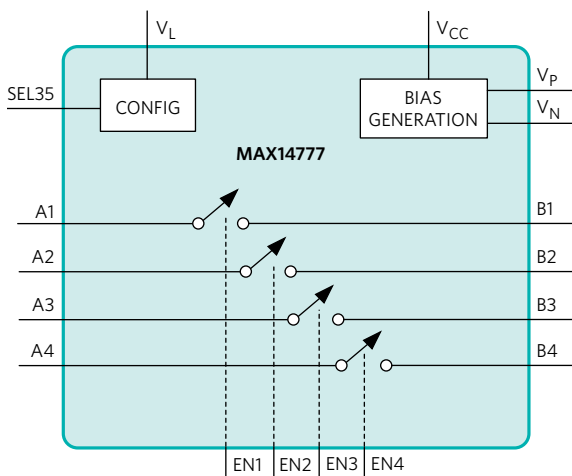


Maxim's Beyond-the-Rails technology simplifies designs by eliminating power supplies previously needed to handle high-voltage input signals.

Analog Switches

MAX14777 Quad Beyond-the-Rails Analog Switch

The MAX14777 quad SPST switch supports analog signals above and below the rails with a single 3.0V to 5.5V supply. The device features a selectable -15V/+35V or -15V/+15V analog signal range for all switches.



Key Features

- -15V/+35V signal range from a single 3.0V to 5.5V supply
- 1.62V to 5.5V logic interface
- High-performance 10Ω R_{ON} (max)
- $150\text{m}\Omega$ (max) R_{ON} flatness
- Small 20-pin TQFN package (4mm x 4mm)
- -40°C to $+105^\circ\text{C}$ operating temperature range

DeepCover Security

Maxim's DeepCover® Secure Authenticators provide a hardware-based solution to provide cryptographic protection against intellectual property theft, counterfeiting, unauthorized access, and other forms of cyber espionage that can compromise industrial systems. We build in security at the hardware level, so designers can be assured that the underlying foundation of algorithms and data remains secure and that higher level applications can run securely. DeepCover solutions use the industry's strongest cryptographic algorithms and cloak sensitive data under multiple layers of advanced physical security to provide the most secure key storage possible. We also offer a low-cost secure service to factory-personalize authenticators to OEM specification. This provides a means to preinstall authentication keys and application data prior to device shipment to contract manufacturers, thereby eliminating concerns of exposing sensitive data.

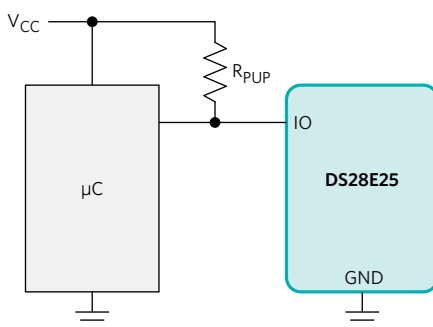
All the DeepCover solutions in this guide are intended for use in industrial applications that require:

- Counterfeit prevention
- Identification and authentication of OEM modules and peripherals
- Reference design license management
- Sensor/accessory authentication and calibration
- System intellectual property protection

DeepCover Secure Authenticators

DS28E25 1-Wire SHA-256 and 4Kb EEPROM

The DeepCover Secure Authenticator ([DS28E25](#)) combines bidirectional secure challenge-and-response authentication with a FIPS 180-based Secure Hash Algorithm (SHA-256) implementation. Highly secure memory stores a secret-key for SHA-256 operations. Additional user-programmable memory is used to store application-specific data. The DS28E25 communicates over Maxim's single-contact 1-Wire® interface.



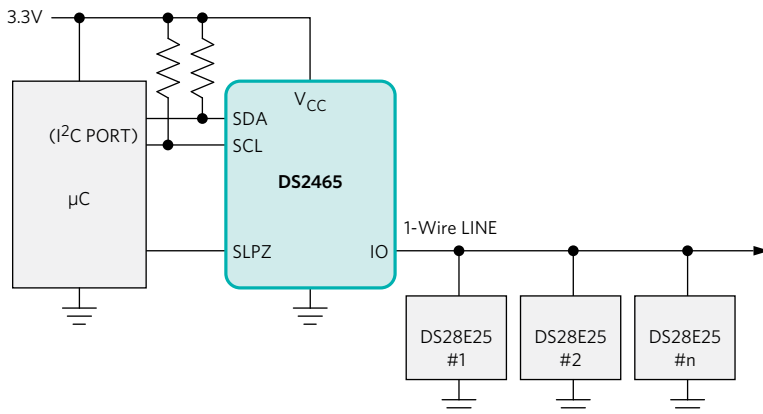
Key Features

- Symmetric-key secure authentication with a bidirectional model
- FIPS 180-based HW-accelerated SHA-256 engine
- 4Kb user EEPROM with programmable protection options including SHA-256 authenticated, W/R protect, and OTP/EPROM mode
- Single-contact 1-Wire interface for host communication
- ±8kV HBM ESD protection (typ) for IO pin
- Operating range: 3.3V ±10%, 1.8V ±5%, -40°C to +85°C

DeepCover Secure Authenticators (cont.)

DS2465 SHA-256 Coprocessor and 1-Wire Master

The DeepCover Secure Authenticator (DS2465) SHA-256 coprocessor with 1-Wire master offloads SHA computations from a host processor and provides a 1-Wire master interface to communicate with 1-Wire slave devices such as the DS28E25. It securely stores a SHA-256 secret-key using DeepCover die-level protection techniques. With an I²C control interface and 1-Wire master port, the DS2465 also performs protocol conversion between the I²C master and any of the attached 1-Wire SHA-256 slaves.



Key Features

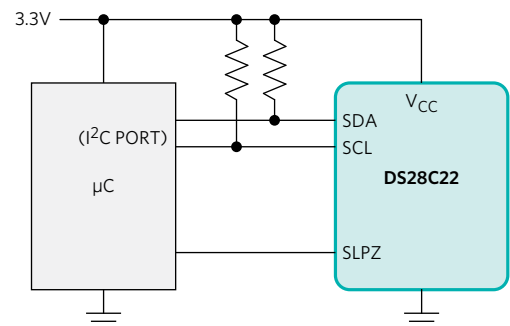
- FIPS 180-based SHA-256 engine to operate symmetric-key-based secure authentication
- 256 bits user EEPROM with multiple programmable protection options
- I²C interface for communication and control
- 1-Wire master port
- Operating range: 3.3V \pm 10%, -40°C to +85°C

DS28C22 I²C SHA-256 and 3Kb EEPROM

With a FIPS 180-based SHA-256 hardware engine, the DeepCover Secure Authenticator (DS28C22) provides bidirectional, secure challenge-and-response authentication and offers optional small message encryption functionality when performing R/W operations on stored data. A 3Kb user-programmable EEPROM array provides nonvolatile storage for application data. Additional protected memory holds a read-protected secret for SHA-256 operations. Each device has its own guaranteed unique and unalterable 64-bit ROM identification number (ROM ID) that is factory programmed into the chip. This unique ROM ID is used as a fundamental input parameter for cryptographic operations and also serves as an electronic serial number within the application. A bidirectional security model enables two-way authentication and encryption between a host system and slave-embedded DS28C22. Slave-to-host authentication is used by a host system to securely validate that an attached or embedded DS28C22 is authentic. Host-to-slave authentication is used to protect DS28C22 user memory from being modified by a nonauthentic host. Optional encrypted small message read and write between host and slave is implemented using a SHA-256 generated one-time pad.

Key Features

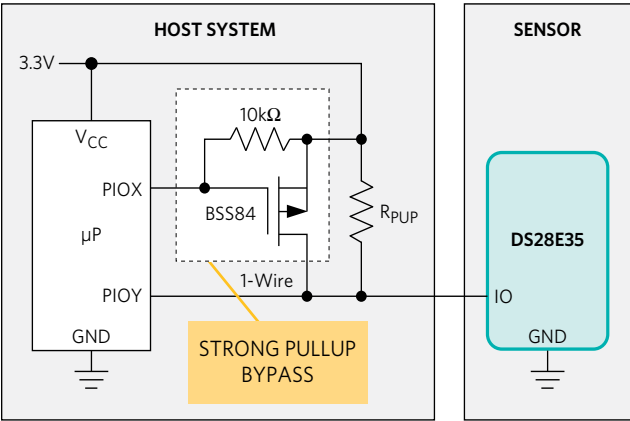
- Bidirectional symmetric-key secure authentication
- FIPS 180-based HW-accelerated SHA-256 engine
- 3Kb user EEPROM with programmable protection
- Optional EEPROM data encrypted R/W with one-time pad
- I²C interface supporting 100kHz and 400kHz
- Operating range: 3.3V \pm 10%, -40°C to +85°C



DeepCover Secure Authenticators (cont.)

DS28E35 1-Wire ECDSA and 1Kb EEPROM

The DeepCover Secure Authenticator (DS28E35) provides a highly secure public-key based solution for a host controller to authenticate peripherals and modules. System solution cost and key management benefit from the FIPS 186 Elliptic Curve Digital Signature Algorithm (ECDSA)-based implementation. This public-key (asymmetric) solution eliminates the need for a host processor to securely protect its authentication key since exposure of the public key is not a security risk. Additionally, native support for public-key certificates provide a flexible and secure solution for OEMs to manage authorized subsystem suppliers. The DS28E35 also features a one-time settable and nonvolatile, 17-bit, decrement-on-command counter that is designed for secure use control of the object to which the DS28E35 is attached.



Key Features

- FIPS 186-based ECDSA engine to operate a public-key authentication model
- Hardware random number generator for key pair creation and ECDSA computation
- 17-bit one-time settable, nonvolatile decrement-on-command counter
- 1Kb user EEPROM with programmable protection options including, write and read protect, and OTP/EPROM mode
- Single-contact 1-Wire interface for host communication
- ±8kV HBM ESD protection (typ) for IO pin
- Operating range: 3.3V ±10%, -40°C to +85°C

Selector Table: DeepCover Secure Authenticators

Part	Description	Features	Benefits
DS2465	SHA-256 coprocessor with 1-Wire master	FIPS 180-based authentication; tamper protection for authentication key, I ² C to 1-Wire conversion	Offloads SHA-256 processing, protects system authentication key, and simplifies host-side 1-Wire I/O.
DS28E25	1-Wire SHA-256 authenticator	FIPS 180-based bidirectional authentication, 4Kb user EEPROM	Authenticate peripherals, protect intellectual property, securely store end-product feature settings, manage approved suppliers, and protect NV memory for application data.
DS28C22	I ² C SHA-256 authenticator	FIPS 180-based bidirectional authentication, 3Kb user EEPROM with optional encrypted R/W of data	
DS28E35	1-Wire ECDSA authenticator	FIPS 186-based public-key authentication, 1Kb user EEPROM, public-key certificate memory, decrement-only usage counter	

Accurate Measurement and Control

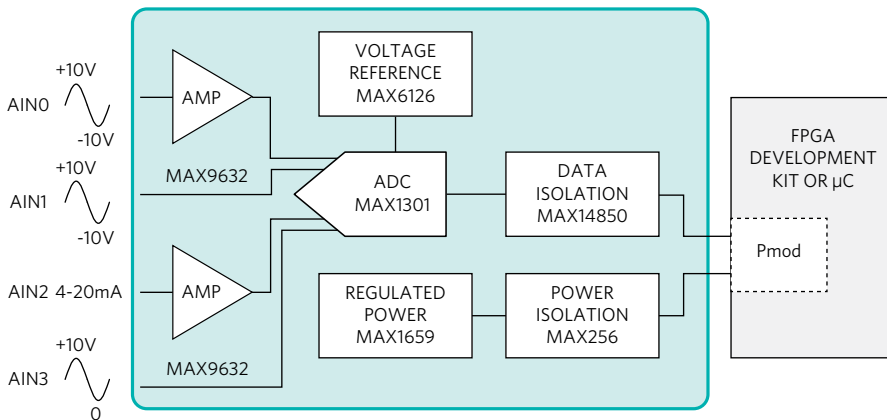
Analog Input Reference Designs

When it comes to measuring analog signals from your industrial process, proven reference designs speed the process of selecting the components that work best together. Here are several 16-bit analog input reference designs for industrial applications.

Schematics, layout files, BOM, test data, and firmware for the Pmod™-compatible reference designs are available for quick prototyping and immediate evaluation on the Xilinx® ZedBoard™ and Nexys™3 systems.

Cupertino (MAXREFDES5#) 16-Bit, High-Accuracy, Multi-Input Isolated AFE Reference Design

The Cupertino (MAXREFDES5#) subsystem reference design is a 16-bit, high-accuracy, industrial analog front-end (AFE) that accepts -10V to +10V, 0 to 10V, and 4-20mA current-loop signals with isolated power and data integrated into a small form factor.



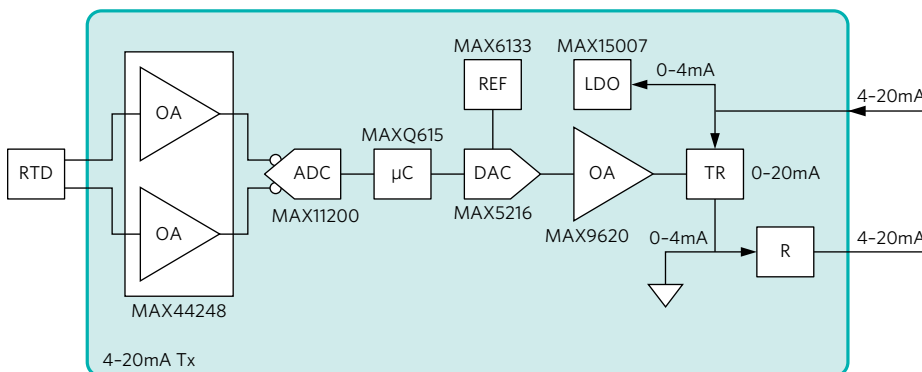
The Cupertino subsystem design block diagram.

Key Features

- High accuracy
- $\pm 10\text{V}$, 0 to 10V, and 4-20mA inputs
- Isolated power and data
- Device drivers
- Example C source code
- Pmod-compatible form factor

Monterey (MAXREFDES15#) 4-20mA Loop-Powered Sensor Reference Design

The Monterey (MAXREFDES15#) subsystem reference design is a high-accuracy, industrial loop-powered sensor transmitter that connects to any standard PT1000 resistance temperature sensor and converts the linearized temperature to a 4-20mA current signal, which is immune to noise and remains constant over long distances.



The Monterey subsystem design block diagram.

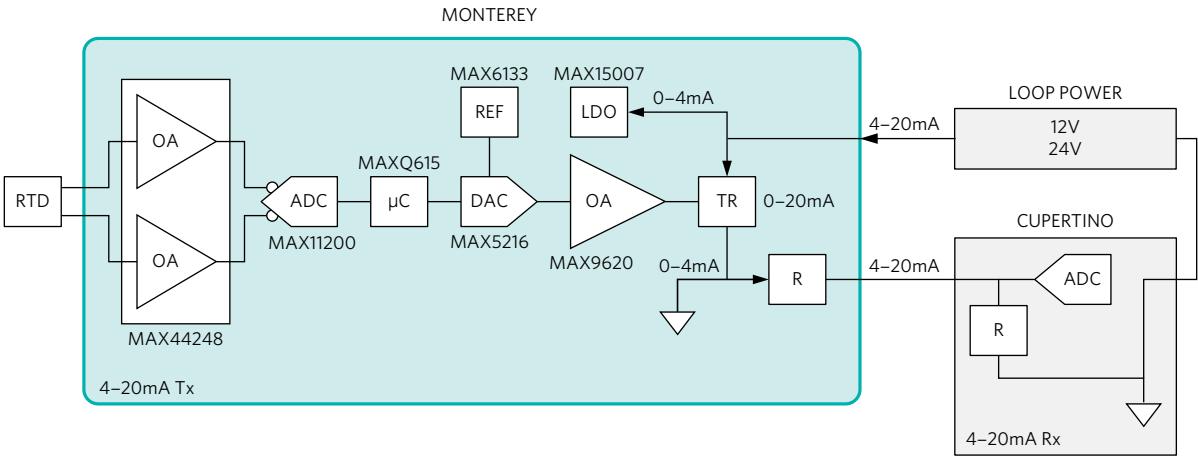
Key Features

- Ultra-low power
- -100°C to $+100^{\circ}\text{C}$ RTD temperature
- High accuracy and precision
- Simple power supply and wide input range
- System current consumption less than 2.1mA
- Resolution 10,000 counts or 0.01%

Analog Input Reference Designs (cont.)

Loop-Powered Temperature Transmitter/Receiver Solution

By combining our Monterey and Cupertino subsystem reference designs, we realize a high-precision, ultra-low-power, 4–20mA, loop-powered temperature transmitter and receiver solution. This combination of designs targets the most demanding applications, yielding a very high-accuracy, high-precision, low-power solution. The Monterey design achieves 0.01% accuracy while drawing only 2.1mA.



The Monterey and Cupertino reference designs create a 4–20mA, loop-powered temperature transmitter and receiver solution.

Industrial Op Amps

To handle large industrial signal ranges, the front-end op amp needs large signal handling capability, while maintaining high DC precision, low power, and low noise. For the ultimate in low-noise performance, Maxim has achieved single-digit nV/ $\sqrt{\text{Hz}}$ performance.

For the ultimate in DC precision, Maxim's auto-zero amplifiers keep the long-term drift so low that we achieve single-digit μV of input offset voltage over time and temperature.

Selector Table: Industrial Op Amps

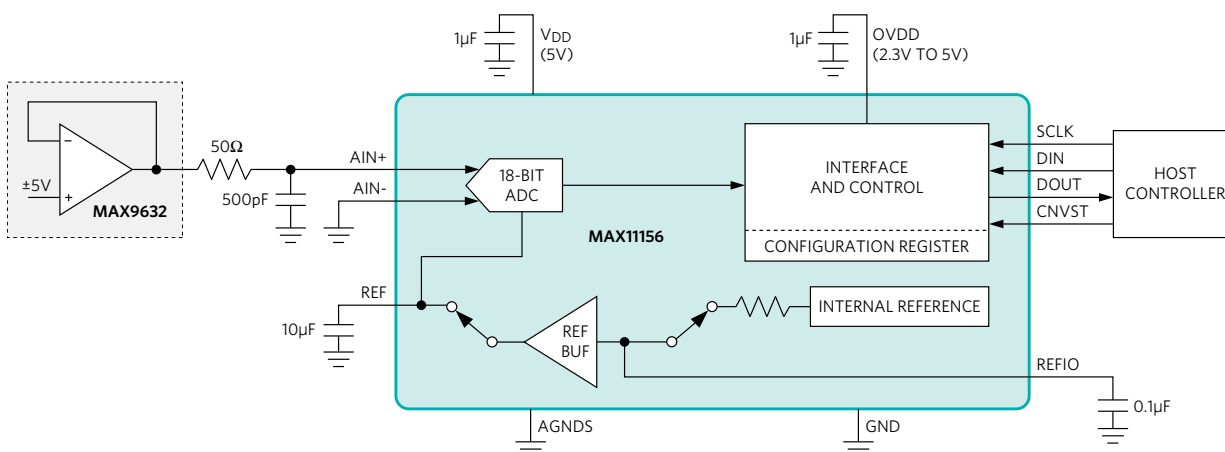
Part	Description	Features	Benefits
MAX44241/246/243	36V, low-noise, precision, single/dual/quad op amps	2.7V to 36V power-supply range, ultra-low input V_{OS} : 5 μV (max), low 9nV/ $\sqrt{\text{Hz}}$ noise at 1kHz	Deliver low noise and precision in high-voltage applications.
MAX44248/245	36V, precision, low-power, 90 μA , dual/quad op amps	Very low input voltage offset 7.5 μV (max), low 30nV/ $^{\circ}\text{C}$ offset drift (max), low 90 μA quiescent current per amplifier	Deliver low noise and precision in low-power applications.
MAX44250/251/252	20V, ultra-precision, low-noise single/dual/quad op amps	2.7V to 20V power-supply range, 6 μV input offset voltage (max) at room temp, low 5.9nV/ $\sqrt{\text{Hz}}$ noise	Wide operating voltage range, shutdown saves power, industry's lowest noise and auto-zero precision in a SOT-23 package.
MAX9632/33	36V, precision, low-noise, wide-band single/dual amplifiers	0.94nV/ $\sqrt{\text{Hz}}$ ultra-low input voltage noise, very fast 600ns settling time to 16-bit accuracy, gain-bandwidth product 55MHz	Small TDFN package saves space; fast settling ideal for an ADC buffer.

ADCs

To enable smaller high-performance, low-power industrial AFEs, with the ability to handle bipolar inputs that go beyond the rails, Maxim developed the [MAX11156](#). This 18-bit, 500ksps, SAR ADC enables the smallest possible solution (3mm x 3mm), without the need for an external reference. And, as a Beyond-the-Rails device, only a single power supply is needed. Performance is also enhanced since bipolar signals do not need to be converted to single-ended signals for input to the ADC.

Key Features

- 18-bit resolution with no missing codes
- SNR: 94.6dB, THD: -105dB at 10kHz
- Internal reference and reference buffer
- Tiny 12-pin, 3mm x 3mm TDFN package
- Bipolar $\pm 5V$ analog input range
- 26.5mW at 500ksps

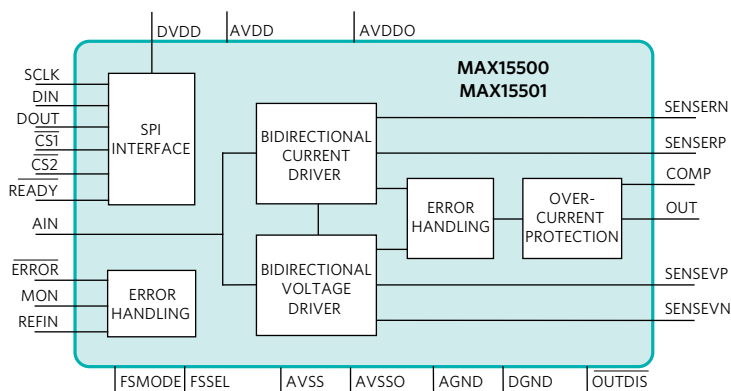


Selector Table: ADCs

Part	Description	Features	Benefits
MAX11156	18-bit, 500ksps, $\pm 5V$ SAR ADC with internal reference in TDFN	No missing codes, SNR: 94.6dB, THD: -105dB at 10kHz, 3mm x 3mm, 12-pin TDFN package	Integrated reference and reference buffer saves space and cost; true bipolar measurements above and below ground improve system accuracy.
MAX11154	18-bit, 500ksps, 0 to 5V SAR ADC with internal reference in TDFN	No missing codes, SNR: 93.5dB, THD: -105dB at 10kHz, 3mm x 3mm, 12-pin TDFN package	Internal or external reference modes add flexibility; integrated reference buffer saves the space and cost of an external amplifier.
MAX11100/01	16-/14-bit, +5V, 200ksps SAR ADC with 10 μA shutdown	No missing codes, small 10-pin μMAX^{\circledR} and WLP packages, low power: 140 μA at 10ksps	Single-supply operation saves cost; logic level (2.7V to 5.25V) saves level shifter; serial interface simplifies isolation.
MAX11200/10	24-bit, single-channel, ultra-low power, delta-sigma ADCs with GPIO	Ultra-low power dissipation; operating-mode < 300 μA (max); programmable gain (1, 2, 4, 8, or 16) (MAX11210); four SPI-controlled GPIOs for external mux control	Low 230 μA supply current meets 4–20mA loop current budget; high resolution improves accuracy; GPIOs reduce isolators for mux control.
MAX11213	16-bit, single-channel, ultra-low power, delta-sigma ADC with programmable gain and GPIO	16-bit noise-free resolution, ultra-low power dissipation, operating mode current drain < 300 μA (max); programmable gain (1 to 128)	Software-adjustable output rates allow speed vs. ultra-low noise tradeoffs.

DACs and Output Conditioners

Maxim's precision digital-to-analog converter (precision DAC) product line is the industry's largest portfolio of products. Our comprehensive offering features small WLP packaging, high-accuracy multichannel devices (up to 32 channels), the industry's first true 16-bit DAC with ± 1 LSB INL, and also the industry's first 1.8V supply DAC. For accurate control and safety, our industrial analog current/voltage output conditioners include the industry's first programmable output current up to ± 24 mA or voltage up to ± 12 V. See the below selector table for a small sampling of available solutions.



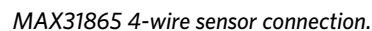
Selector Table: DACs and Output Conditioners

Part	Description	Features	Benefits
MAX5705/02/15/25	Ultra-small, single-, dual-, quad-, octal-channel, 12-bit buffered output voltage DACs with internal reference and SPI interface	Programmable interface watchdog timer (MAX5725 only), three precision selectable internal references, wide 2.7V to 5.5V supply range	Watchdog version flags communication breakdown; feature-rich 1-/2-/4-/8-channel DAC family in a WLP footprint saves board space and cost; independent 1.8V to 5.5V digital I/O power-supply input adds flexibility.
MAX5214/16	14-/16-bit, low-power, buffered output, rail-to-rail DACs with SPI interface	Low power consumption (80 μ A max), guaranteed monotonic over all operating ranges, wide 2.7V to 5.25V supply range	Minimize power consumption; improve system performance with high resolution, high accuracy, and high precision; integrated buffer reduces the board space needed.
MAX5316/18	16-/18-bit, high-accuracy voltage output DAC with digital gain, offset control, and SPI interface	INL accuracy guaranteed with ± 2 LSB (max) over temperature, buffered voltage output directly drives 2k Ω load rail-to-rail, no external amplifiers required	Lowest noise, fast-settling precision 16-/18-bit DACs improve system speed and accuracy; integrated output and reference buffers save development time, development cost, and PCB area.
MAX15500/01	Industrial analog current/voltage output conditioners	Programmable output (plus overrange); ± 10 V, 0 to 10V, 0 to 5V; ± 20 mA, 0 to 20mA, 4mA to 20mA; HART compliant; SPI interface, with daisy-chain capability	Extensive error reporting through the SPI interface enhances system safety; protected against short-circuit/overcurrent output conditions.

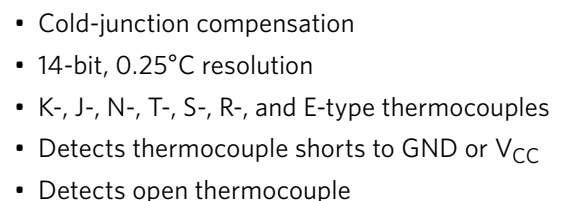
Thermocouples and RTDs (resistance temperature detectors) are the most common industrial sensors for temperature due to their ability to handle very wide temperature ranges, but interfacing to them is not easy. They must be properly biased and their signals properly linearized to realize their potential accuracy and precision. Any loss of signal from these sensors can be a critical problem since they are usually an integral part of the temperature control loop. To help our customers realize simple and reliable solutions to these challenges, Maxim developed single IC sensor digitizer solutions for both thermocouples and RTDs. The solutions bias these sensors, handle the cold junction compensation needed for thermocouples, have many built-in fault detections, and provide digital outputs.

The **MAX31865** RTD-to-digital converter is optimized for platinum RTDs. An external resistor sets the sensitivity for the RTD being used and a precision delta-sigma ADC converts the ratio of the RTD resistance to the reference resistance into digital form. The MAX31865's inputs are protected against overvoltage faults as large as $\pm 50V$. Programmable detection of RTD and cable open and short conditions is included.

- Simple conversion of platinum RTD (PT100 to PT1000)
- Compatible with 2-, 3-, and 4-wire sensor connections
- 15-bit ADC resolution
- Total accuracy: 0.5°C (0.05% of full scale) max
- ±50V input protection
- Multiple sensor fault detections



The **MAX31855** thermocouple-to-digital converter is a single IC solution that provides functionality similar to the MAX31865, but digitizes the signal from K-, J-, N-, T-, S-, R-, and E-type thermocouples. It includes the necessary cold junction compensation. It allows readings as high as +1800°C and as low as -270°C.



MAX31913 Industrial Interface Serializer

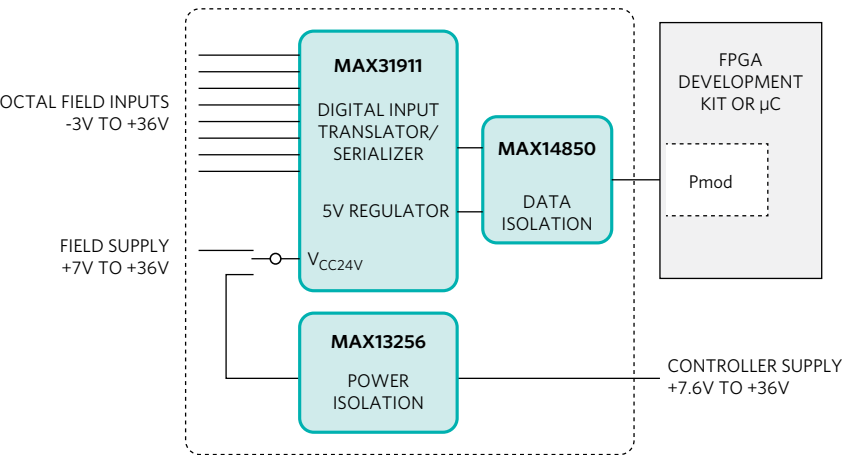
- Eight high-voltage input channels (36V max)
- Configurable for IEC 61131-2 input Types 1, 2, 3
- Selectable input filtering and debouncing from 0 to 3ms
- Configurable input current limiting from 0.5mA to 6mA
- On-chip 5V regulator
- On-chip 24V field supply voltage monitor
- Multibit CRC code generation and transmission for error
- Field-side energyless LED drivers



Digital Input Serializers (cont.)

Digital Input Reference Design

The Corona ([MAXREFDES12#](#)) reference design is an isolated octal digital input solution made from just three ICs that, when compared to the traditional approach, provides significantly reduced size, power dissipation, component count, isolation channels, processor I/O port usage, and cost.



Key Features

- Eight high-voltage input channels (36V max)
- On-chip 8-to-1 serialization with SPI interface
- On-chip 5V regulator
- Isolated power and data
- Example C source code
- Pmod-compatible form factor

Selector Table: Digital Input Serializers

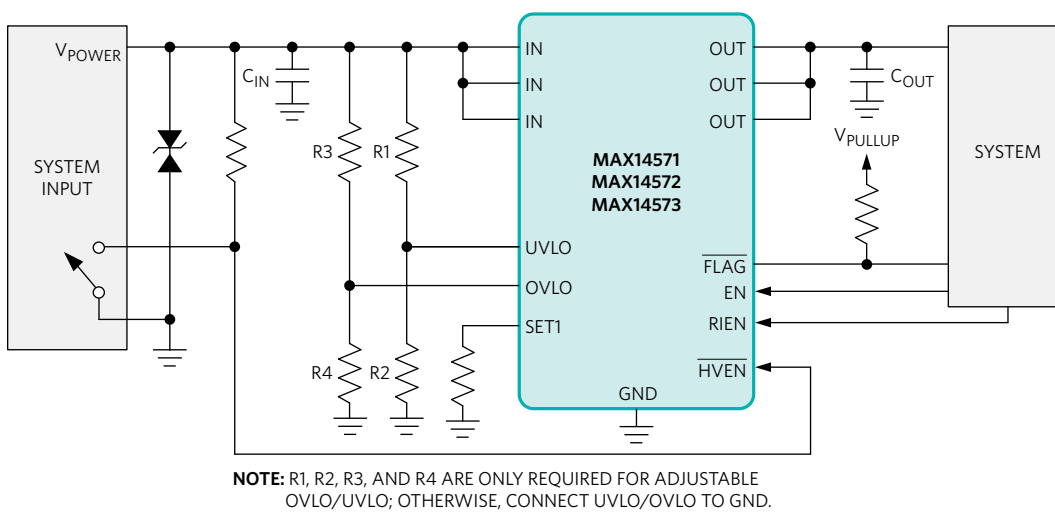
Part	Description	Features	Benefits
MAX31911	Octal, digital input translator/serializer	Programmable on-chip current limiter, on-chip serializer, 3-bit CRC	Lowest-in-class power dissipation; only three optocouplers required; reliable data transfer.
MAX31913	Octal, digital input translator/serializer with LED drivers	Programmable on-chip current limiter, 5-bit CRC, field-side energyless LED drivers	Lowest-in-class power dissipation; only three optocouplers required; reliable data transfer.

Overvoltage/Overcurrent Protectors

The [MAX14571](#)/[MAX14572](#)/[MAX14573](#) are industrial protection ICs that combine high overvoltage up to 36V and overcurrent protection accurate up to 4.2A in a small 14-pin TSSOP (5mm x 6.5mm) package with integrated FETs that have low 100mΩ (typ) R_{ON} . The back-to-back FETs provide positive and negative input overvoltage protection and reverse current protection. Besides eliminating the need for discrete components, these parts are up to one-third smaller than comparable IC solutions with external FETs. The individual parts in this family offer the choice of turning off after a 20.7ms (typ) blanking time, latching after the blanking time, or continuous current limiting at the threshold. All these devices operate over the extended -40°C to +85°C temperature range.

Key Features

- Wide 4.5V to 36V operating input range
- Adjustable current limit up to 4.2A
- 100mΩ (typ) on-resistance FET
- ±3% accurate preset voltage thresholds
- ±15% accuracy current limit

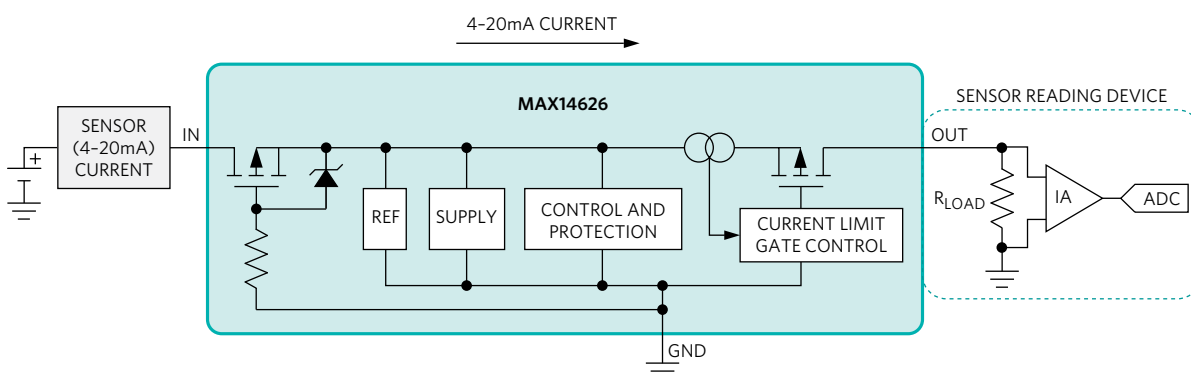


MAX14626 Current Loop Protector

The [MAX14626](#) current loop protector is the industry's first 4mA to 20mA integrated current loop protector. It features a current-limit switch set to 30mA to prevent damage to the analog input module from sensor failure. The current-limit switch features low 25Ω (typ) on-resistance to significantly lower power dissipation compared to discrete solutions consisting of a PTC poly switch, zener diodes, and resistors.

Key Features

- +2.3V to +40V wide supply voltage range
- Low on-resistance 25Ω (typ)
- Accurate ±10% current limit
- Reverse input protection
- Low operating current



IO-Link Master and Device Transceivers

The [MAX14820](#) and [MAX14821](#) transceivers are suitable for IO-Link devices and 24V binary sensors/actuators. All specified IO-Link data rates are supported. Additional 24V digital inputs and outputs are provided. Two internal linear regulators generate common sensor and actuator power requirements: 5V and 3.3V.

On-board C/Q and DO drivers are independently configurable for push-pull, high-side (pnp), or low-side (nnp) operation. The device detects the IO-Link C/Q wake-up condition and generates a wake-up signal on the active-low WU output.

The MAX14820 is available in a 4mm x 4mm, 24-pin TQFN package, and the MAX14821 is available in both a 4mm x 4mm, 24-pin TQFN package and a 2.5mm x 2.5mm, 25-pin WLP package. Both devices are specified over the extended -40°C to +85°C temperature range.

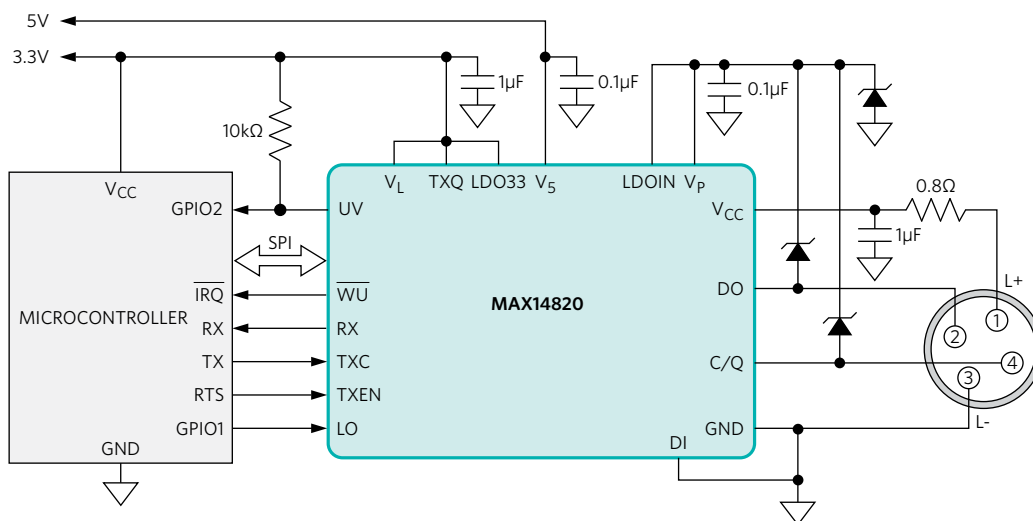
Key Features

- IO-Link v1.0 and v1.1 physical layer compliant
- Supports COM1, COM2, and COM3 data rates
- IO-Link device wake-up detection
- Push-pull, high-side, or low-side outputs
- 300mA (MAX14820) and 100mA (MAX14821) specified C/Q output drive
- Extensive fault monitoring and reporting
- TQFN (MAX14820/MAX14821) and WLP (MAX14821 only) packages



 **WLP**
 (2.5mm x 2.5mm)
  **TQFN**
 (4mm x 4mm)

The USB drive is only shown for size reference.



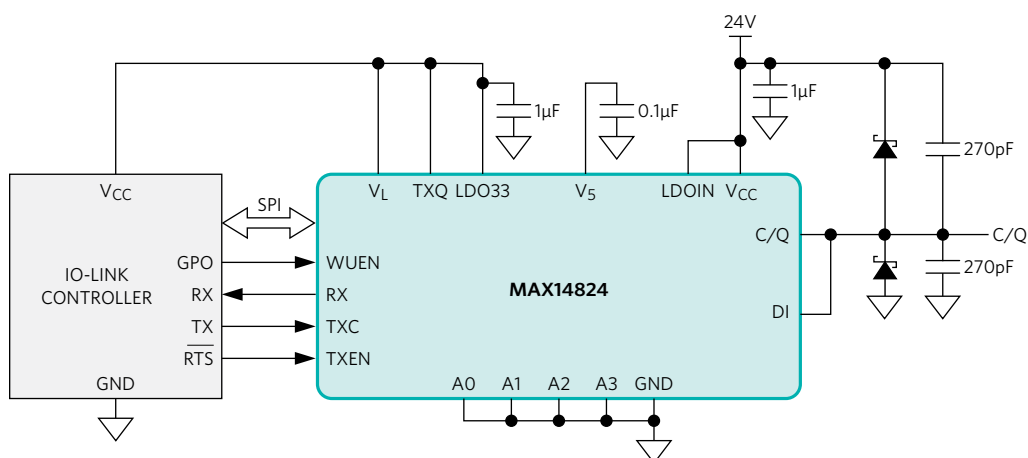
IO-Link Master and Device Transceivers (cont.)

MAX14824 IO-Link Master Transceiver

The MAX14824 is an IO-Link master interface that integrates an IO-Link physical layer transceiver with an auxiliary digital input and two linear regulators. High-port-count IO-Link master applications are supported through in-band SPI addressing, and the 12MHz SPI interface minimizes host controller access times. In-band addressing and selectable SPI addresses enable cascading up to 16 devices.

Key Features

- IO-Link v1.0 and v1.1 physical layer compliant
- Supports COM1, COM2, and COM3 data rates
- 300mA C/Q output drive
- Generates 500mA wake-up pulse
- -40°C to +105°C operating temperature range
- 4mm x 4mm TQFN package



Selector Table: IO-Link Transceivers

Part	Description	Features	Benefits
MAX14820	IO-Link device transceiver	IO-Link v1.0 and 1.1 compliant, 300mA output drive, reverse polarity and short-circuit protection	Reduced solution footprint; low power consumption.
MAX14821	IO-Link device transceiver	Small 2.5mm x 2.5mm package, IO-Link v1.0 and v1.1 compliant, reverse polarity and short-circuit protection	Smallest size enables more compact sensor designs; low power consumption.
MAX14824	IO-Link master transceiver	500mA WU pulse generation, IO-Link v1.0 and 1.1 compliant, reverse polarity and short-circuit protection	Easily scalable to 16 channels with in-band SPI addressing.
MAX14830	Quad UART with integrated FIFOs	128-word FIFOs, SPI or I ² C interface, synchronized transmit capability	Reduced processor overhead; UART expansion optimal for IO-Link applications.

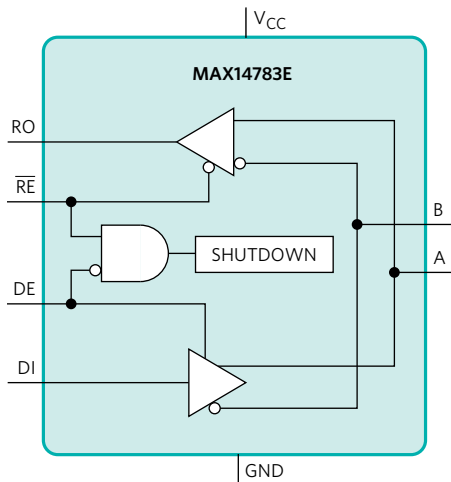
RS-485 Transceivers

To continue our leadership position in providing the most robust interface technology in the industrial market, the **MAX14783E** is a 3.3V/5V ESD-protected transceiver intended for half-duplex RS-485/RS-422 communication up to 42Mbps. The device is optimized for high speeds over extended cable runs, while maximizing tolerance to noise.

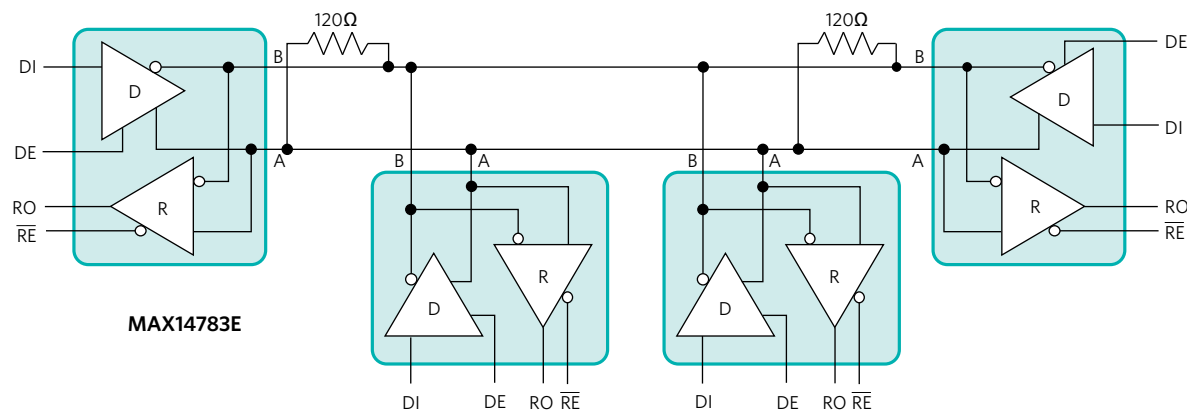
The MAX14783E integrated protection features include short-circuit-protected outputs, hot-swap functionality, and a true fail-safe receiver that guarantee a logic-high receiver output when inputs are shorted or open. Hot-swap capability eliminates undesired transitions on the bus during power-up or hot insertion.

Key Features

- Integrated protection increases robustness
- $\pm 35\text{kV}$ HBM ESD
- Short-circuit protected outputs
- True fail-safe receiver
- Hot-swap capability
- -40°C to $+125^{\circ}\text{C}$ operating temperature range



The MAX14783E matches the industry standard pinout while protected to $\pm 35\text{kV}$ HBM ESD.



Typical half-duplex RS-485 network using the MAX14783E.

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Rev. 1; January 2014

