Industrial Solution

July, 2014

INTEGRATED FACTORIES

From the shop floor to the top floor,
manufacturing is coming together

ABCs of Port Protection - MAX14588

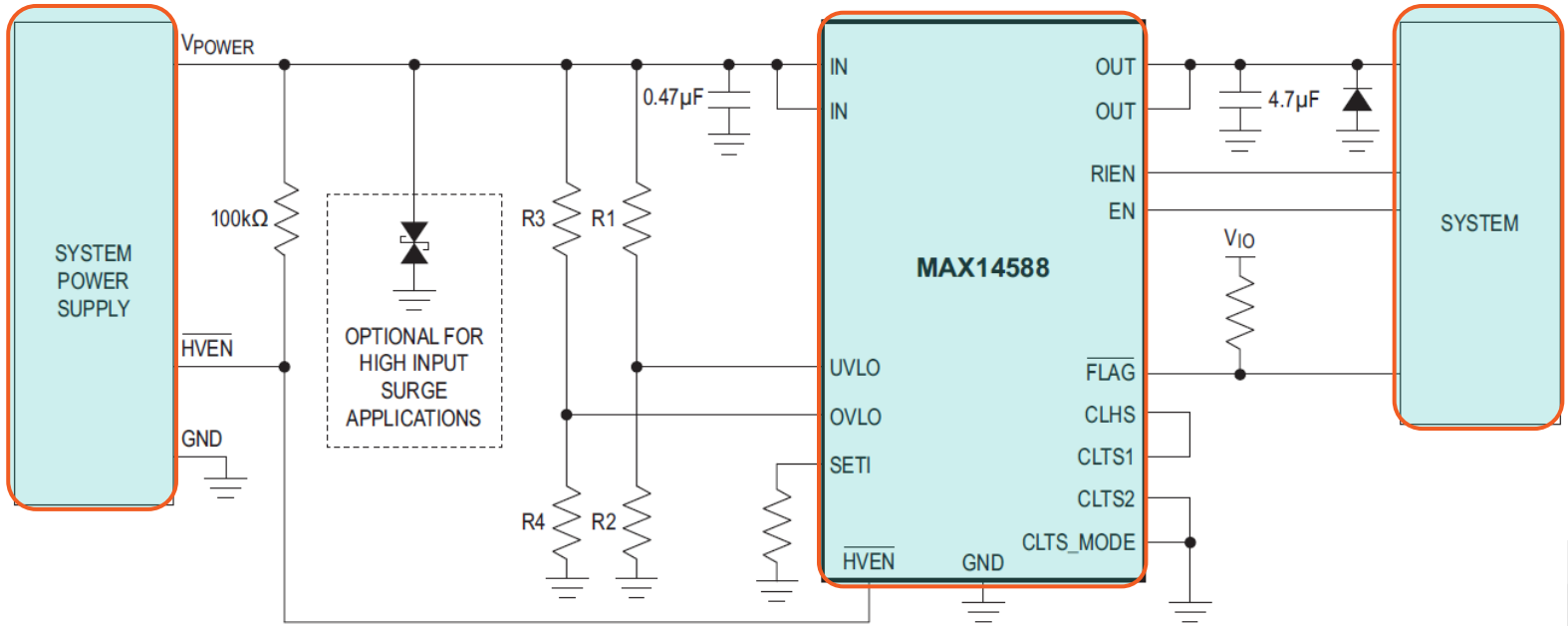
MAX14588 System Block Diagram

Space Saving Design

- ✓ Integrated N-FET and P-FET
- ✓ Fewer discrete components required
- ✓ Smaller board space needed

Robust Protection

- ✓ Guaranteed high voltage & high current protection
- ✓ Internal sense resistor for reliable limiting
- ✓ Ability to monitor die temp for thermal shutdown



maxim integrated™

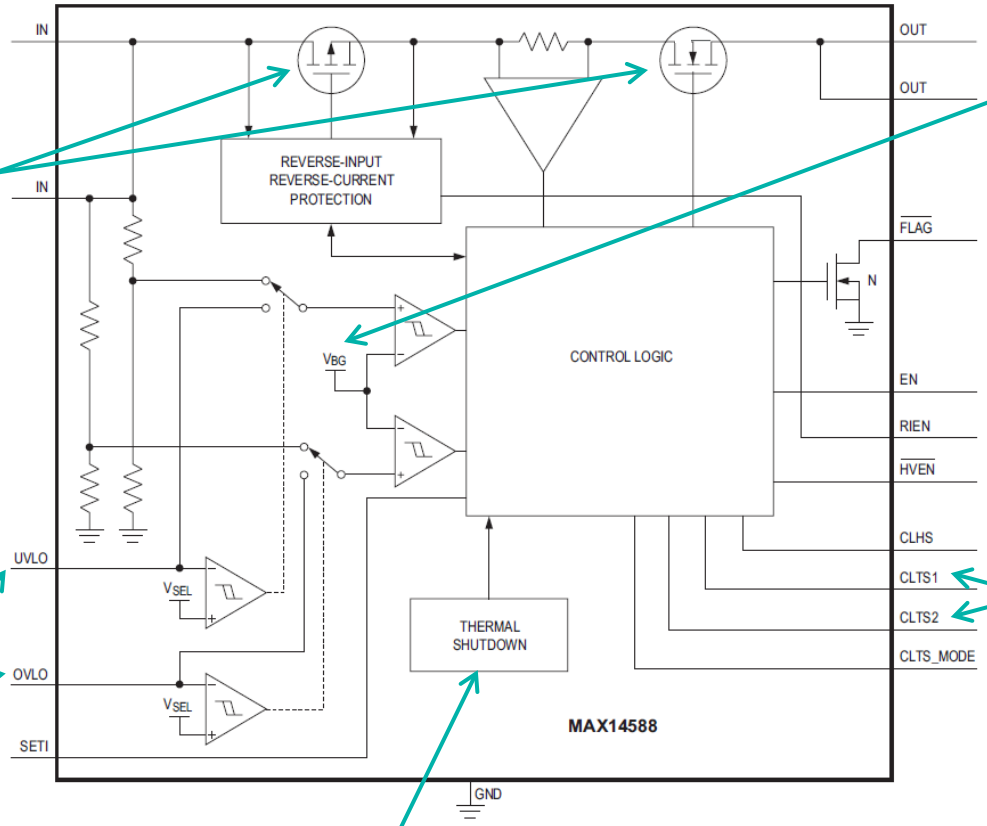
Maxim Solution

The MAX14588 is a robust protection IC with several features:

- ✓ Overvoltage & overcurrent protection up to 1A
- ✓ Reverse current & short circuit protection
- ✓ Positive and negative voltage faults
- ✓ Integrated NFET and PFET
- ✓ Thermal shutdown protection
- ✓ Fault indication
- ✓ Pin-selectable fault response

MAX14588 Key Differentiators

Back-to-back FETs provide reverse current & negative input voltage protection



Accurate thresholds over full temp range significantly increase reliability

Voltage and current thresholds can be easily adjusted via resistors

Pin-selectable fault response modes make it flexible and easy to re-use in different projects

Thermal shutdown increases safety

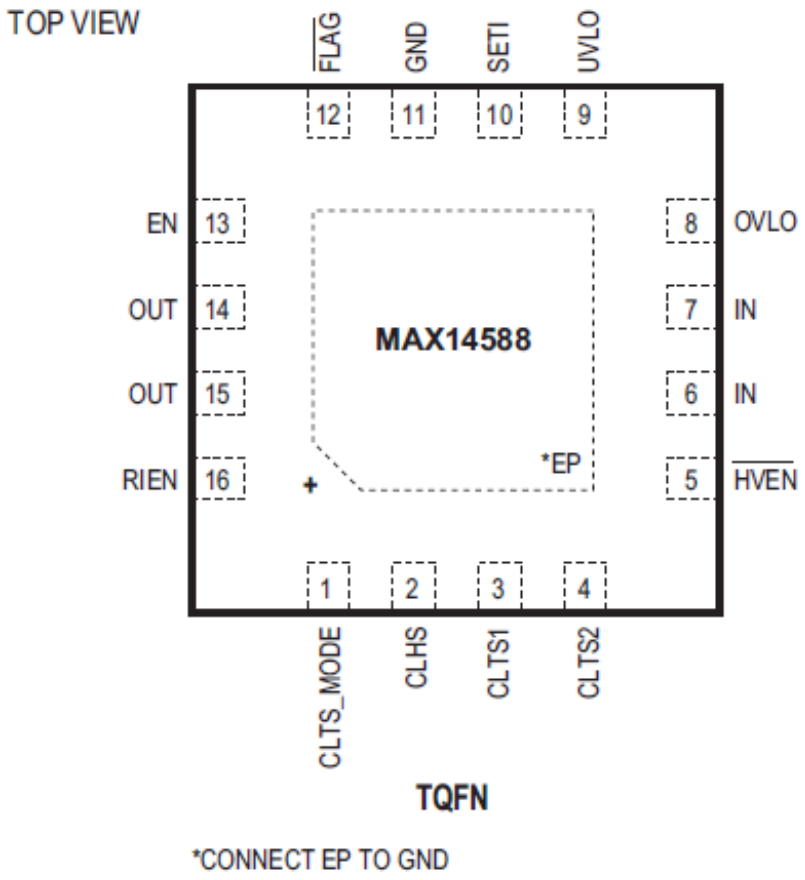
CLTS2	CLTS1	CURRENT-LIMIT TYPE
0	0	LATCH OFF
0	1	AUTORETRY
1	0	CONTINUOUS
1	1	CONTINUOUS

maxim integrated™

MAX14588 1A Overcurrent & Overvoltage Protector

Industry's most space-efficient & robust integrated protection IC

3mm x 3mm TQFN Package



maxim integrated™

MAX14588 1A Overcurrent & Overvoltage Protector

Industry's most space-efficient & robust integrated protection IC

Benefits

- Small **3mm x 3mm TQFN pkg** saves board space
- User-selectable current limit make it easier to reuse across different platforms
- Extended operating temperature

Features

- Up to 36V overvoltage, 1A overcurrent protection
- Programmable Autoretry, latchoff & continuous current limit modes programmed via CLTS pins
- -40°C to +125°C guaranteed operating temperature
- **Low 190mΩ R_{ON} integrated FET**

End Applications

- PLC Systems
- Control & Automation Equipment
- Human Machine Interfaces

maxim integrated™

Industrial Precision Converter Solutions

Customer Needs for ADC…

- High Speed Reading
- Fast Step Response
  - > ADC settling time / transient response time
  - > Signal Conditioning Settling time

- High Accuracy
- High Resolution

Accuracy and Resolution are NOT the same.

Difference between Accuracy and Resolution

- Accuracy
  - > What does it mean?
  - > Which is the equivalent electrical influence factor?
- Resolution
  - > What does it mean?
  - > Which is the equivalent electrical influence factor?
- Precision
  - > What does it mean?

Accuracy vs. Precision

- Accuracy → Bias (systematic error)
- Short term Repeatability → Random Noise (random error)
- **Error** should be **“Acceptable”**
- **Error** must be well **“Defined”**

Bias Error Sources

- Gain error
- Offset error
- Linearity error

High Speed Read and Fast Settling Time

- High Speed Read –> Sampling Rate > 200ksps
  - > SAR ADC sampling rate < 3msps
    - (MAX11190 3msps)
  - > Sigma Delta sampling rate <1msps
    - (MAX11040K 64ksps)

1/2 Channels 0.5/2/3Msps 8/10/12 Bit SAR ADC low power SPI Digital IF

New MAX111xx family

	8-bit	10-bit	12-bit
3 Msps	MAX11111 MAX11116	MAX11106 MAX11117	MAX11103 MAX11108*
2 Msps	MAX11115	MAX11110	MAX11102 MAX11105
500 ksps	MAX11662 MAX11661	MAX11664 MAX11663	MAX11666 MAX11665

Legend

- 2-Channel
- 1-Channel

16 ADCs
1CH SOT23-6
2CH uMAX-10
2CH TDFN-10

* MAX11108
Ultra Thin QFN-10
1.6mm x 2.1mm

maxim integrated™

4/8/16 Channels, 0.5/1/3Msps, SAR ADC, 8/10/12 Bit, low power, SPI Digital IF

New MAX111xx family with Sample Set Feature

	8-bit	10-bit	12-bit
3 Msps		MAX11129	MAX11131*
		MAX11130	MAX11132
1 Msps	MAX11126	MAX11127	MAX11128
	MAX11123	MAX11124	MAX11125
	MAX11120	MAX11121	MAX11122
500 ksps	MAX11143	MAX11140	MAX11137
	MAX11142	MAX11139	MAX11136
	MAX11141	MAX11138	MAX11135

Legend

- 16-Channel
- 8-Channel
- 4-Channel

22 ADCs
Pin to Pin
SW compatible
5x5mm TQFN-28

* MAX11131 available also in TSSOP-EP/28

maxim integrated™

4/8/16 Channels, 0.5/1/3Msps, SAR ADC, 10/12 Bit, low power, SPI Digital IF

New MAX113xx family with Sample Set and Post-Mux Access

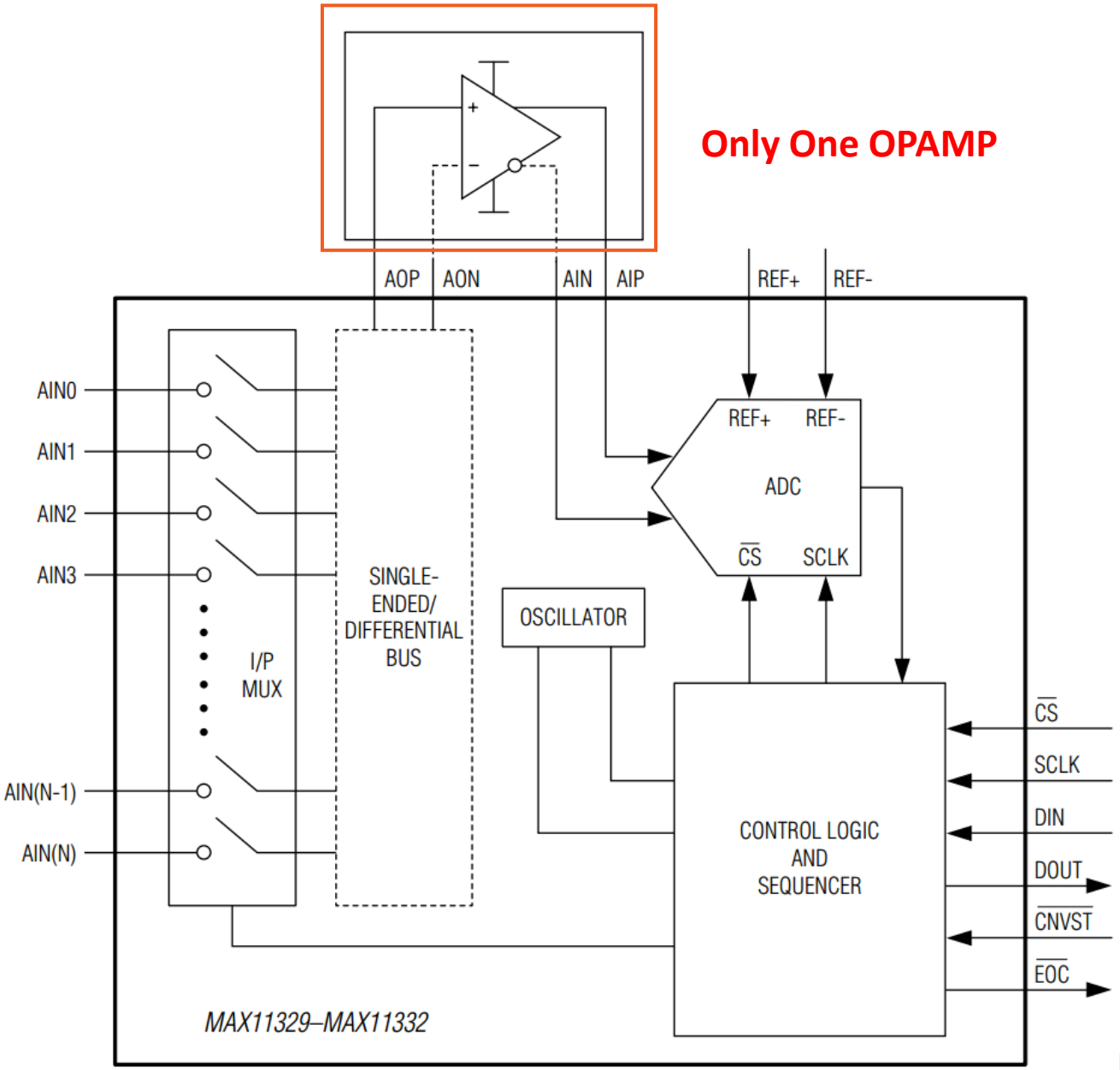
3 Msps		MAX11329 MAX11330	MAX11331 MAX11332
1 Msps		MAX11327 MAX11324 MAX11321	MAX11328 MAX11325 MAX11322
500 ksps		MAX11340 MAX11339 MAX11338	MAX11337 MAX11336 MAX11335
	8-bit	10-bit	12-bit

Legend

- 16-Channel
- 8-Channel
- 4-Channel

16 ADCs
Pin to Pin
SW compatible
5x5mm TQFN-32

maxim integrated™


Only One OPAMP
AOP
AON
AIN
AIP
REF+
REF-
AIN0
AIN1
AIN2
AIN3
AIN(N-1)
AIN(N)
I/P MUX
SINGLE-ENDED/ DIFFERENTIAL BUS
REF+
REF-
ADC
CS
SCLK
OSCILLATOR
CONTROL LOGIC AND SEQUENCER
CS
SCLK
DIN
DOUT
CNVST
EOC
MAX11329–MAX11332

RTD to Digital
MAX31865

Introduction

- Objective
  - Introduce Maxim's new RTD-to-digital converter – MAX31865
- Purpose
  - Brief tutorial of RTD temperature sensors
  - Describe circuit to digitize RTDs using ADCs
  - Introduce the MAX31865, a single-chip solution to this problem
- Content
  - TBD slides
- Learning time
  - TBD minutes

RTD 101

- Pt resistor – thin film or wire-wound
  - > Resistance varies with temperature ~0.39%/°C
- Excellent repeatability and accuracy
- Often called Pt100 or Pt1000
  - > 100Ω or 1000Ω is resistance at 0°C
- Wide temperature range: about -200°C to 850°C
- Number of wires varies
  - > 2-wire for short distances, 3-and 4-wire for long distances

2-, 3-, and 4-Wire RTD Connections

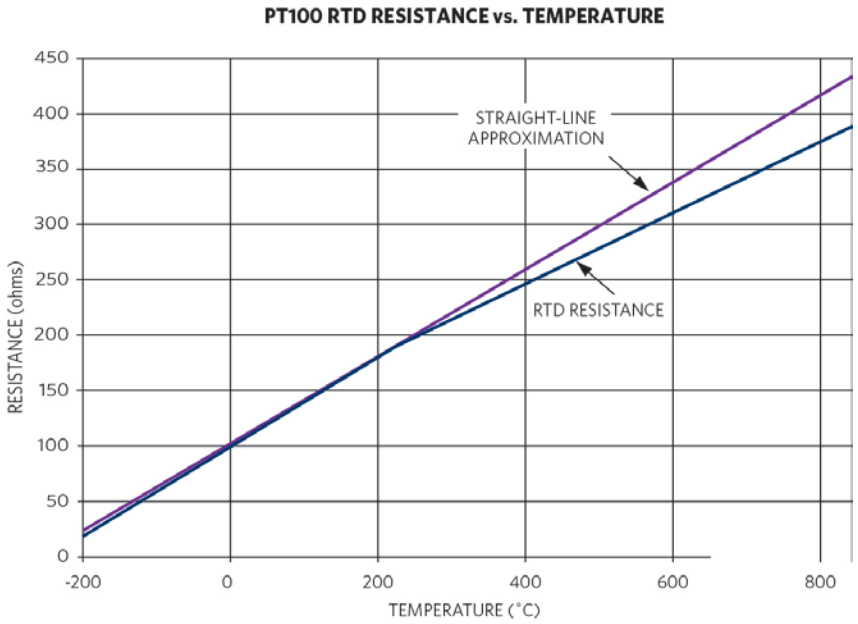
4-Wire: force and sense wires, eliminate effect of cable resistance

3-Wire: if the wire resistances are equal, effect of resistance can be cancelled

2-Wire: good accuracy when wires are short and resistance is negligible

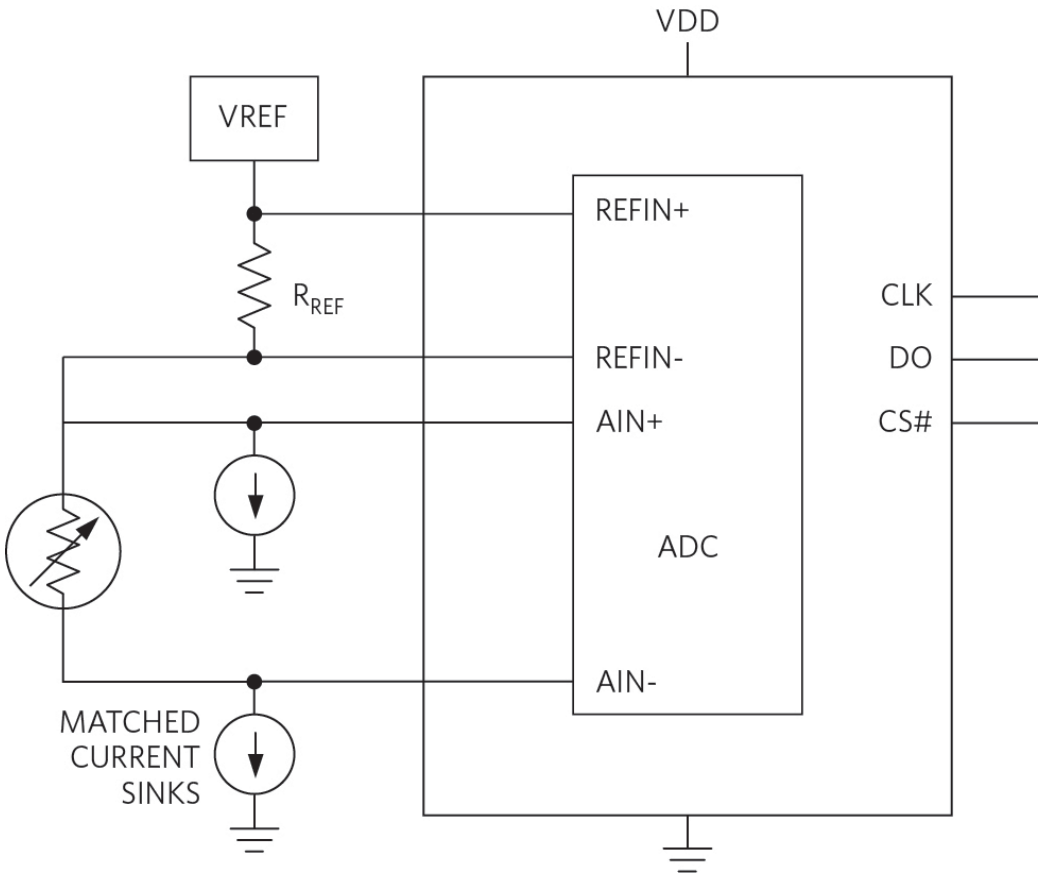
RTD Linearity

- $R(T) = R_0(1 + aT + bT^2 + cT^3 (T - 100))$
  - R(T) = RTD resistance at T
  - T = Temperature (°C)
  - R_0 = Resistance at T=0°C
- For Pt100 (IEC751 standard)
  - $\alpha = 0.00385055$
  - $a = 3.90830 \times 10^{-3}$
  - $b = -5.77500 \times 10^{-7}$
  - $c = 4.18301 \times 10^{-12}$
    - $-200°C \leq T \leq 0°C$
  - $c = 0$
    - $0°C \leq T \leq 850°C$



RTD resistance as a function of temperature is given by the Callendar-Van Dusen equation

Simplified RTD Interface Using an ADC



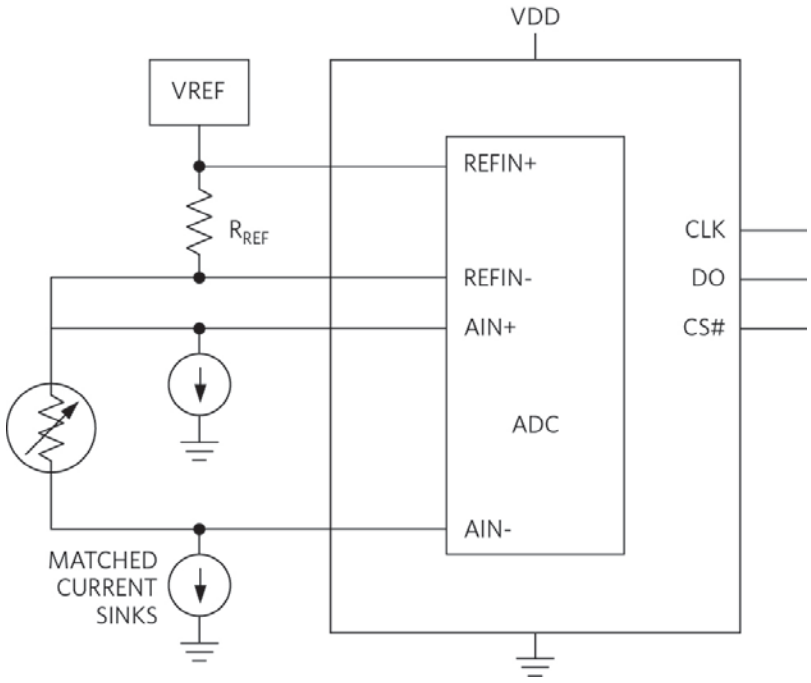
Simplified RTD Interface Using an ADC

3-Wire Example

- Some ADCs have internal current sinks
- Voltage drop on RREF is the reference voltage
- Voltage drop on RTD is measured to determine resistance
- Resistance value is used to determine temperature

Potential Problems

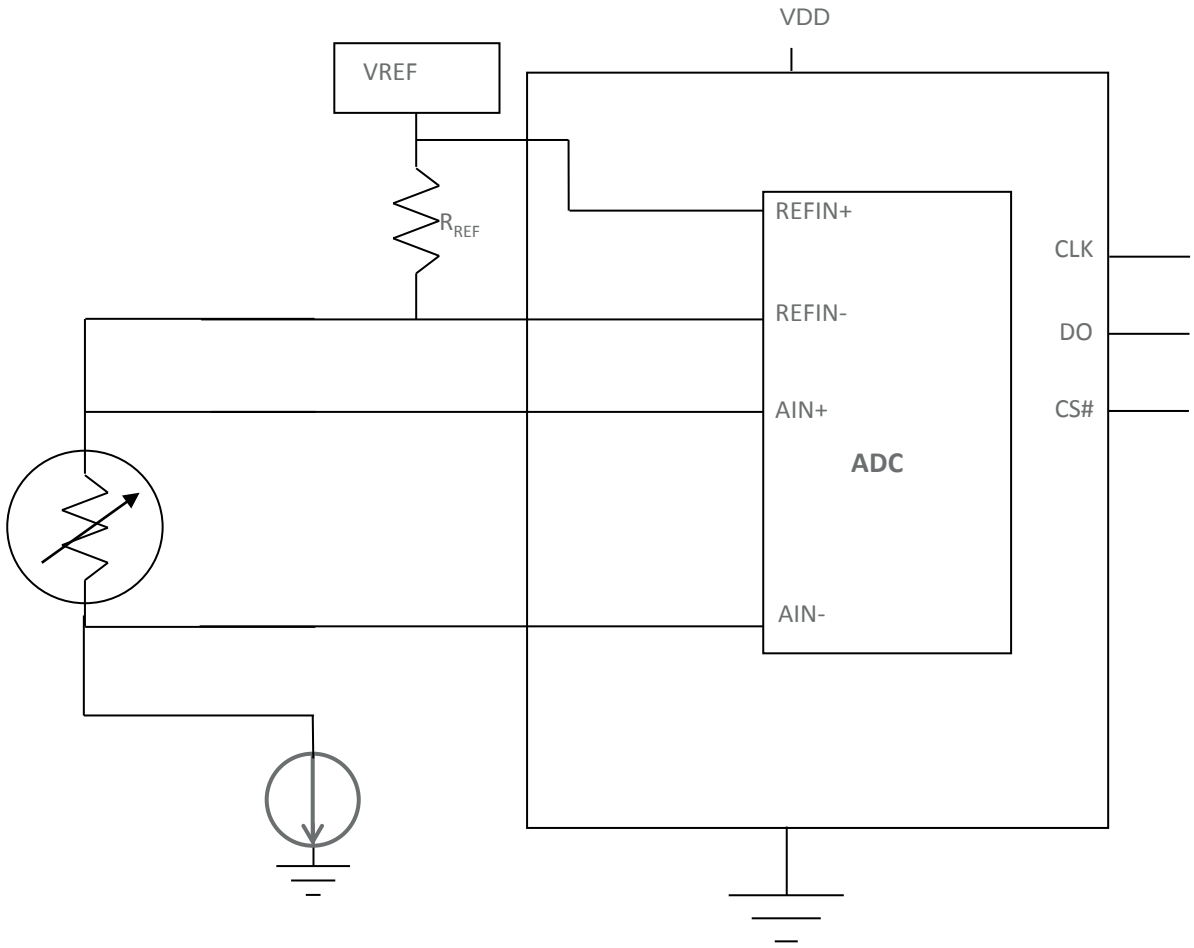
- For 3-wire connection, current source mismatch causes measurement errors
- How do you detect opens, shorts, other faults?
- How do you protect against over-voltages at the inputs?
- Significant design challenges remain



Input Protection

- ADCs will be damaged by input voltages beyond the supply rails
- If the connector or cable can be exposed to excess voltage during use or installation, there is a “potential” for damage
- Adding protection against over-voltages while retaining accuracy can be challenging (and expensive)
- Typical approaches:
  - > Protected multiplexers
  - > Clamps
  - > Large resistors

Fault Detection



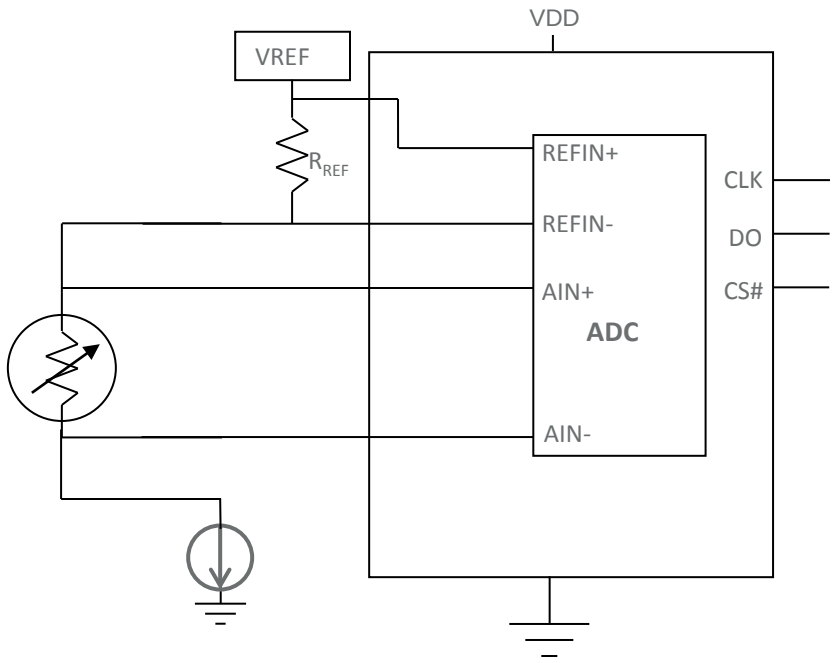
Fault Detection

Easily Detected Faults

- Simple short across the RTD: produces a too-low ADC reading
- Open RTD element: Low reference voltage; full-scale ADC reading

More Difficult Faults

- Short AIN- to ground: Gives reading in the normal range
- Break in current sink wire (FORCE-): Reference voltage and RTD voltage are both very small and undefined – may appear normal



Single-Chip RTD Digitizer

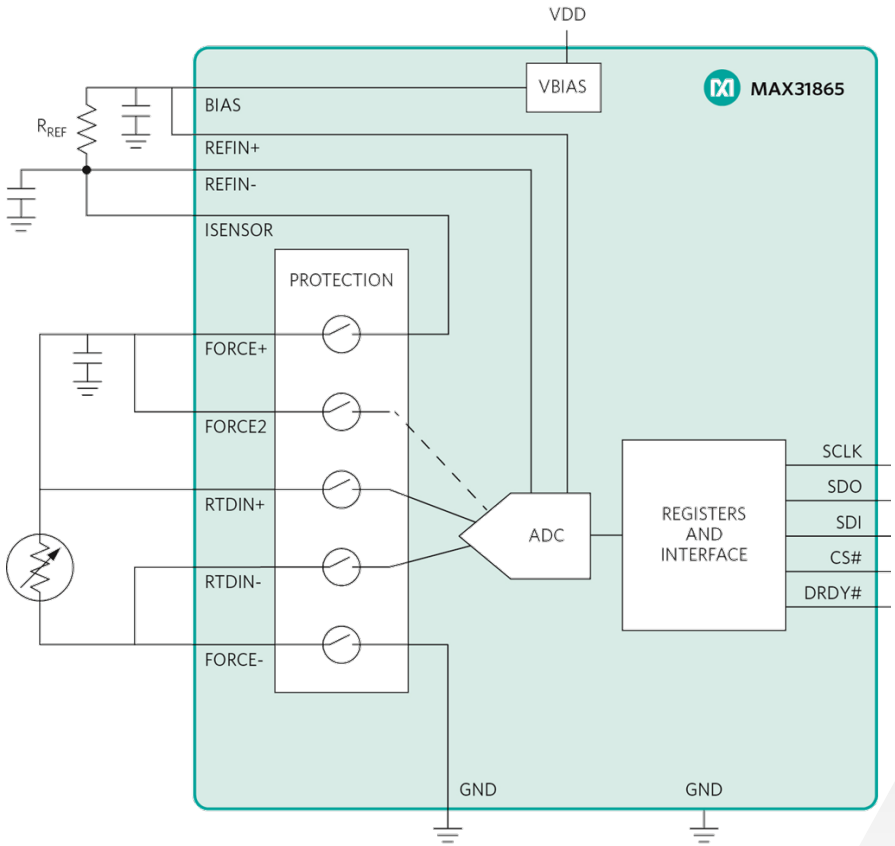
MAX31865

Benefits

- Simple, accurate RTD measurement
- Supports Pt100 and Pt1000 RTDs
- Supports 2-, 3-, and 4-wire RTDs
- No external input protection needed

Features

- Measures temperatures from -200°C to +800°C
- Error less than ±0.5°C
- ±50V input protection
- Detects variety of cable opens and shorts



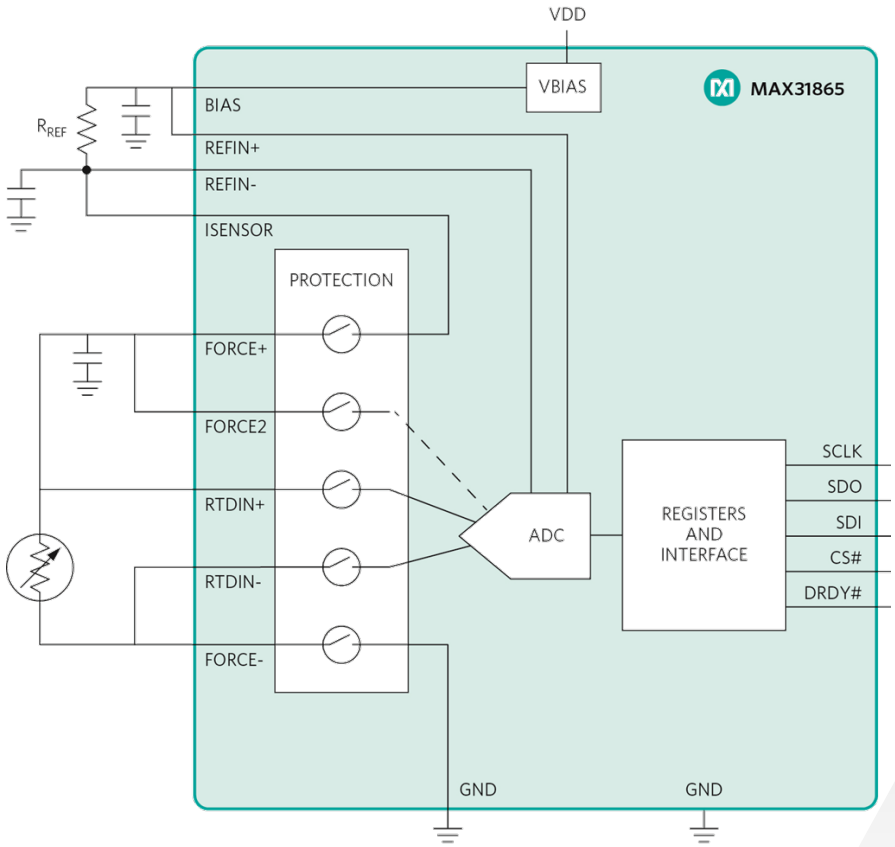
3-WIRE CONNECTION

maxim integrated™

3-Wire Operation with No Current Sinks

How It Works

- Directly measure voltage drop across wire (VFORCE+ - VRTDIN+)
- Subtract from VRTDIN+ - VRTDIN-
- No current sink mismatch errors



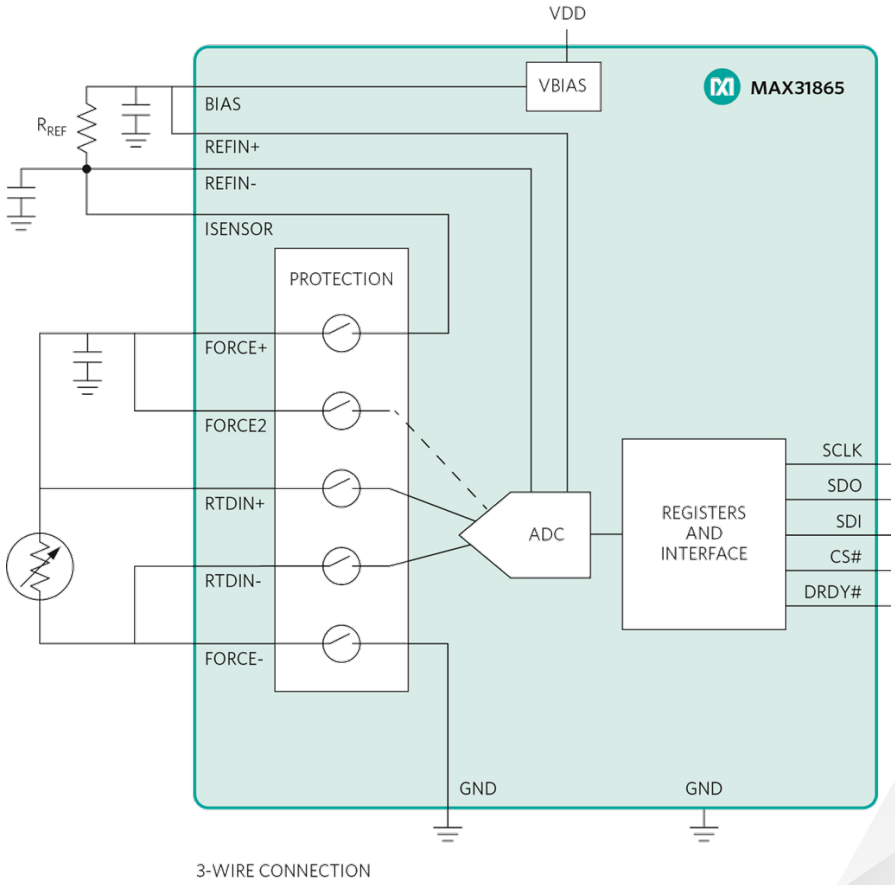
3-WIRE CONNECTION

maxim integrated™

Built-In Input Protection

How It Works

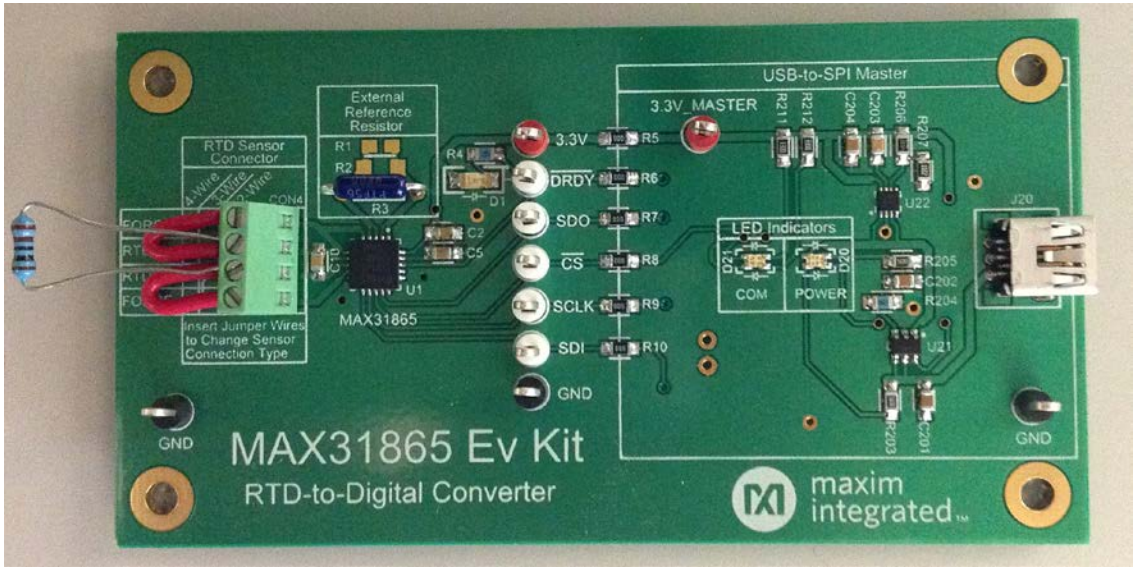
- High-voltage MOSFET analog switches in series with input pins
- If an input voltage is > VDD or < GND, the switch opens
- ±50V over-voltage protection



3-WIRE CONNECTION

maxim integrated™

MAX31865 EVKit

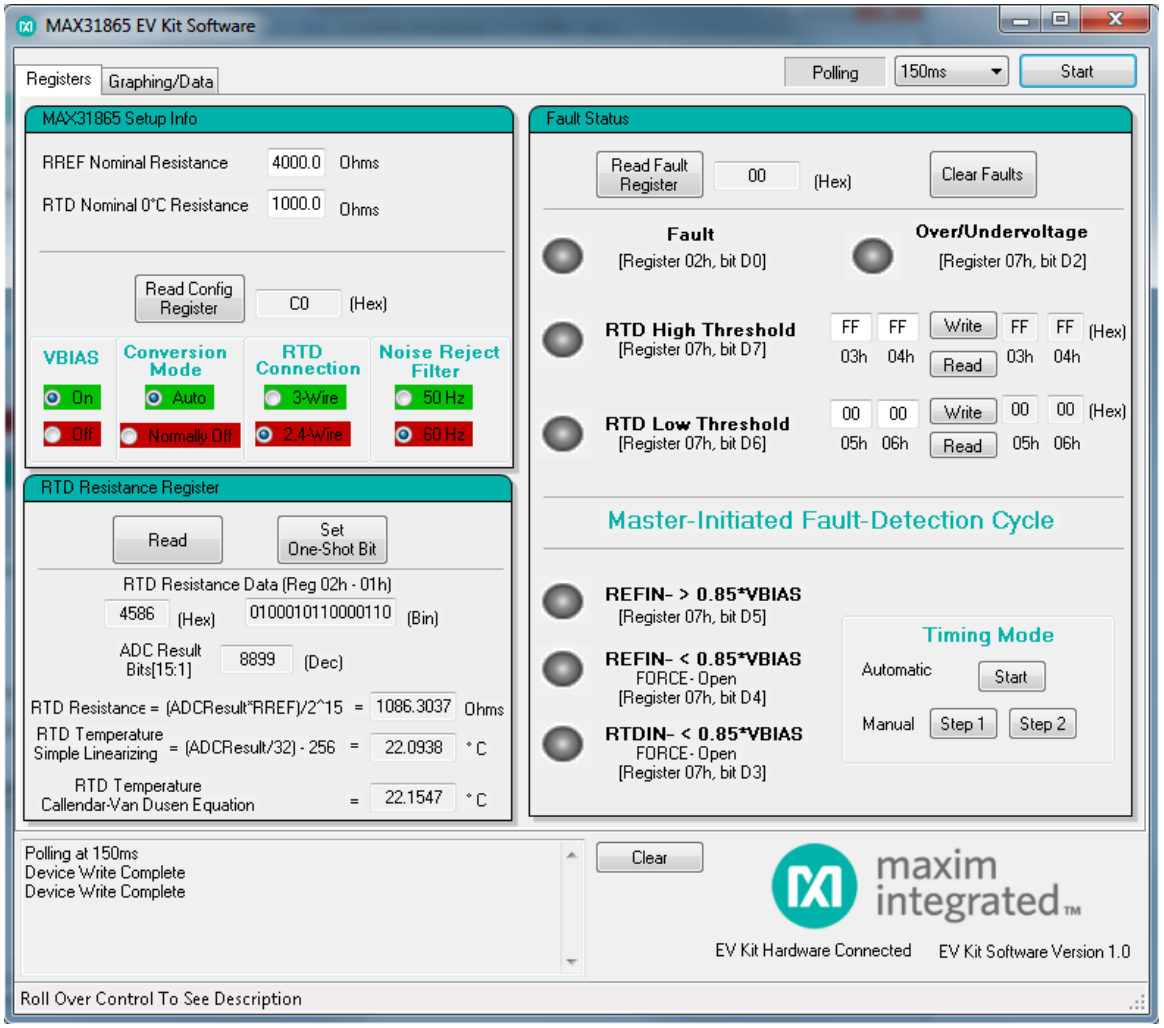


What it does

- Gets you up and running quickly
- Accepts 2-, 3-, and 4-wire RTDs
- User-friendly GUI
- Performs linearization calculations
- Logs measurement data on demand

maxim integrated™

MAX31865 EVKit

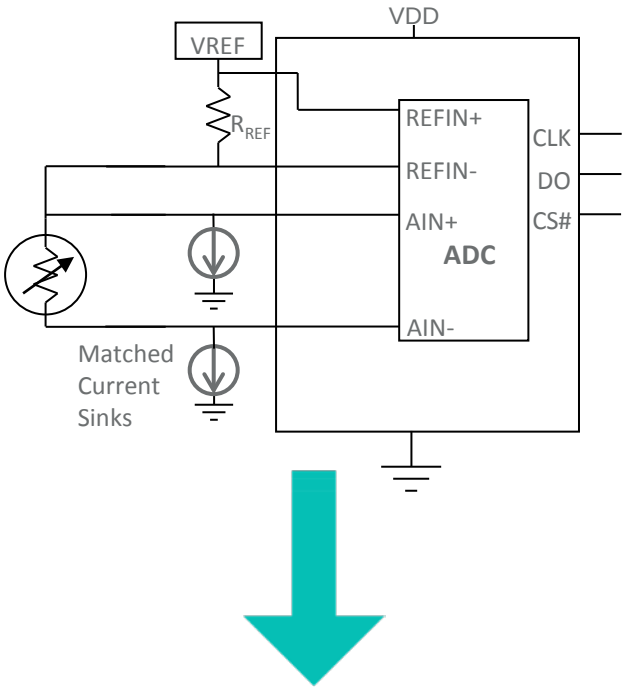


Summary

- RTD advantages
  - > Wide temperature range
  - > Excellent repeatability
  - > Excellent accuracy
- Design challenges
  - > Detecting sensor and cable faults
  - > Input protection
  - > Matched current sources for 3-wire RTDs

Summary

- MAX31865
  - > Simple, single-chip RTD digitizer
  - > Detects a variety of sensor and cable faults
  - > Supports Pt100 and Pt1000 RTDs
  - > No matched current sources needed
  - > ±50V input protection



maxim integrated™

RTD-to-Digital Converter

- MAX31865

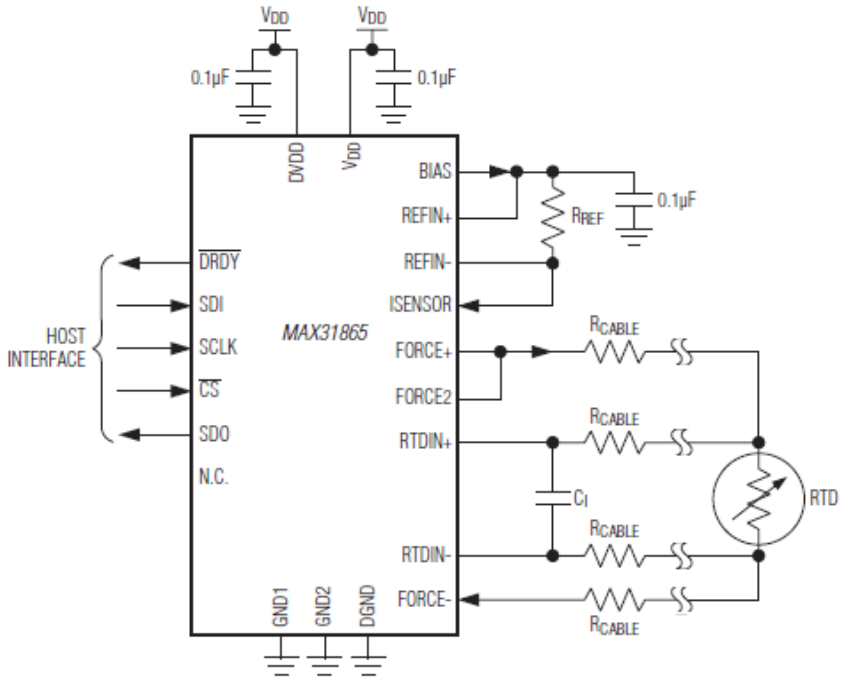
Benefits

- Integrates several functions into one IC to lower system cost, simplify design efforts, and reduce design cycle time
- Flexible design allows use of wide range of RTD values and configurations
- High accuracy aids designers in meeting error budgets

Features

- Handles 100Ω to 1kΩ (at 0°C) platinum RTDs (PT100 to PT1000)
- Compatible with 2-, 3-, and 4-wire sensor connections
- Can also be used with thermistors
- ±50V of input voltage protection
- Fault detection for RTD opens and shorts

4-WIRE SENSOR CONNECTION



End Applications

- Industrial Temperature Controllers & Transmitters
- Instrumentation
- Medical

maxim integrated™