TI Sensors
Accurately measure the real world
Sensors to accurately measure the real world
Design intelligent systems with highly accurate, small-size sensors

- Temperature Sensors
- Humidity Sensors
- mmWave Sensors
- Magnetic Sensors
- Specialty Sensors
- Current Sensors
TI’s sensing journey

- **1977**: 1st Silicon temperature sensor- LM3911
- **1999**: World’s smallest digital temperature sensor- TMP103
- **2011**: Industry’s 1st 16-bit precision current & power monitor INA226
- **2012**: Industry’s highest accuracy ±0.1°C temperature sensor- TMP117
- **2014**: TI’s 1st Hall sensor DRV5013
- **2015**: Industry’s highest precision isolated magnetic current sensor MSC1100
- **2016**: Industry’s 1st current sense amplifier with integrated high-precision, low-drift shunt resistor INA250
- **2018**: Industry’s highest precision isolated magnetic current sensor MSC1100
- **2019**: Industry’s highest sensitivity 2D dual-latch Hall sensor TMAG5110
- **2021**: Antenna on Package 60GHz mmWave sensor IWR6843AOP

**Key Events**:

- **1977**: TI’s 1st Silicon temperature sensor- LM3911
- **1979**: World’s smallest digital temperature sensor- TMP103
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- **2021**: Antenna on Package 60GHz mmWave sensor IWR6843AOP
TI sensing stats

32,000+ number of customers serviced in 2018

3500 TI sensing orderables

1977 1st Silicon Temperature Sensor

315 Unique TI sensing products

279 Sensors supporting extended temperature range beyond 105 degrees

402 Sensing educational resources

0.58mm² CSP Smallest package size offered

132 Sensing EVMs offered

328 Sensing TI Designs

81 Automotive qualified products
Sensing Overview topics

- Current and Power Sensing
- Magnetic / Hall Effect Sensing
- Ultrasonic & Proximity Sensing
- Temperature & Humidity Sensing

- 35°C
Current measurement for closed loop circuits

Infer diagnostic and/or operational system information from the current measurement

Current & Power Measurement Use Cases
Solutions customers seek

Real-time overcurrent protection (OCP)
Current-level detection exceeding a predetermined threshold as system fluctuations occur due to loads and transients

Current and power monitoring for system optimization
Modeling of system performance and energy to maximize efficiency and/or battery life

Current measurement for closed loop circuits
Infer diagnostic and/or operational system information from the current measurement
Current & power monitoring solutions
High precision, cost-optimized solutions for current and power sensing

Why use TI current sensing?
Current sensing products enable higher system efficiency, real-time system protection, and responsive control feedback in both isolated and non-isolated system topologies. Whether simply detecting a fault condition or performing a precise measurement, TI’s current sensors will reliably and accurately sense the current or power in any system.

TI’s current & power monitoring solutions

<table>
<thead>
<tr>
<th>Analog Output</th>
<th>Comparator</th>
<th>In-package Shunt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrates the full analog signal processing and provide a voltage or current output</td>
<td>Provides a simple ALERT signal when the load current exceeds a threshold along with analog or digital out</td>
<td>Offers a low-drift, precision shunt resistor element in-package with either analog or digital out</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digital Monitor</th>
<th>Ambient Field Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrates the full signal conditioning path and utilize a standard 2-wire digital interface</td>
<td>On-chip sensor measures the magnetic field flux density and generates a voltage output proportional to the field strength</td>
</tr>
</tbody>
</table>

Key applications
- **Automotive**
  - HEV/EV DC-DC
  - Electronic power steering
  - Body Control Modules
  - Premium Audio
- **Industrial**
  - Power delivery
  - Test & Measurement
  - Factory Automation
  - Medical

Featured products

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA240</td>
<td>80V Analog Out with enhanced PWM Rejection</td>
</tr>
<tr>
<td>INA381</td>
<td>Cost effective Analog out with integrated comparator</td>
</tr>
<tr>
<td>INA190</td>
<td>40V, High-precision analog out with µA bias current</td>
</tr>
<tr>
<td>INA253</td>
<td>Integrated shunt with enhanced PWM rejection</td>
</tr>
</tbody>
</table>

Links to get started
- Design support
- Current sense training
- Filter Design Tool
- Competitor-cross reference
Current Sensing Use-cases in Industrial

Analog Current Sense Amplifier Use-cases

Brushless DC Motor Commutation
Uses up to three current sense amplifiers in low-side of high-side configurations for torque measurement.

Power Supplies
Current sensing in power supplies for accurate current measurement and quick over-current detection.

PLCs
To avoid that a sensor could create problems for the system, each port monitors the current to ensure proper operation.
Design Considerations:
1) What is the bus voltage range?
2) What is the IC VCC range (is it the same as VBUS?)
   a) What is the sensed output fed into and its VIN range?
3) What is the load current range?
4) How much Voltage drop can the load accept?
5) Power Dissipation of the Sensing element?
6) Is the current going to be Unidirectional or Bi-Directional?
   a) Is it symmetric?
7) Other considerations:
   1) Bandwidth
   2) PSRR
   3) CMRR
   4) Vout swing / Vout drive
   5) Noise
Current Sensing Design Considerations

Analog Current Sense Amplifier Bi-Directional Sensing

- Two Outputs, $V_{\text{REF}}$ and $V_{\text{REF}}/2$, for Convenient Use in Single-Supply Systems
- Excellent Temperature Drift Performance:
  - 8 ppm/°C (max) from −40°C to 125°C
- High Initial Accuracy: ±0.05% (max)
- $V_{\text{REF}}$ and $V_{\text{BIAS}}$ Tracking over Temperature:
  - 6 ppm/°C (max) from −40°C to 85°C
  - 7 ppm/°C (max) from −40°C to 125°C
- Microsize Package: SOT23-5
- Low Dropout Voltage: 10 mV
- High Output Current: ±20 mA
- Low Quiescent Current: 360 μA
- Line Regulation: 3 ppm/V
- Load Regulation: 8 ppm/mA
Current Sensing Design Considerations

Analog Current Sense Amplifier Use-cases

Input filtering and Transient protection

Layout Example

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Hall Effect Position Sensing Use Cases

Solutions customers seek

**Absolute Position Measurement**
Precise absolute position measurement for linear and angular movements

**Proximity Detection**
Detect the presence/absence of a magnetic field based on predefined operating and release thresholds of magnets

**Rotational Sensing**
Enable rotary encoding or motor commutation utilizing a latch-type or linear hall sensors
Magnetic Hall effect sensors
Low power, highly reliable, cost-optimized solutions for magnetic position sensing

Why use TI magnetic hall effect sensors?
Known for robust durability and dependable operation, TI magnetic Hall effect sensors are the simplest solution for any position sensing application. Whether simply detecting the closing of a lid/surface or performing complex motor commutation, TI’s Hall effect sensors will reliably and accurately sense the position in any system.

TI’s magnetic hall effect sensors

<table>
<thead>
<tr>
<th>Position measurement</th>
<th>Proximity detection</th>
<th>Rotational sensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precise absolute position of linear and angular movements using linear hall sensors</td>
<td>Detect presence or absence of a magnetic field for simple on/off or open/close applications using hall effect switches</td>
<td>Speed and direction for rotary encoding and rotor position for motor commutation using hall effect latches or linear hall sensors</td>
</tr>
</tbody>
</table>

Key applications

- **Automotive**
  - Body motors
  - Buttons & Switches
  - Electric power steering
  - LIDAR
- **Industrial**
  - Cordless garden/power tools
  - E-meters
  - Door & window sensors
  - Motor drive

Featured products

<table>
<thead>
<tr>
<th>DRV5013</th>
<th>DRV5015</th>
<th>DRV5032</th>
<th>DRV5055</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5V to 38V hall effect latch</td>
<td>2mT, 5.5V High sensitivity hall effect latch</td>
<td>Ultra-low power 1.65V to 5.5V hall effect switch</td>
<td>High accuracy 3.3V or 5V bipolar linear hall effect sensor</td>
</tr>
</tbody>
</table>

Links to get started

- Design support
- Hall effect sensor training
- Application notes
- Competitor-cross reference

Texas Instruments
Hall-effect Use-cases in Industrial

Digital Latches and Switches Use-cases

**Brushless DC Motor Commutation**
Uses three Hall-effect latches to sense each phase for 3-phase motor commutation.

- Hall sensor output for position and speed calculation
- PWM input to drive motor speed

**Flow Meter**
Hall effect switch detects when each magnetized rotor blade passes, calculating water flow by the number of pulses triggered in a certain timeframe.

Linear Hall Use-cases

**E-meter Tamper Detection**
Hall linear devices are used to detect the presence of a large magnetic field usually in 2D (usually two single-axis devices) or 3D (typically single-chip solution).

**Linear Trigger**
Linear response to accurately determine the position of a trigger button for speed control.

Key Products
# Why use TI ultrasonic sensing?

TI’s integrated ultrasonic sensing ICs can drive a variety of transducers over a wide detection range. The small size and accurate performance of the TI ultrasonic solutions enable the integration of proximity sensing and collision avoidance feature in a wide variety of industrial and automotive applications.

## TI’s Ultrasonic sensors

<table>
<thead>
<tr>
<th>Accurate detection</th>
<th>System flexibility</th>
<th>Integrated solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accurately detect objects with a resolution of 1mm – 1cm at a range of 10cm – 10m</td>
<td>Detect near and far objects of various shapes, sizes, colors and transparencies through air or liquid</td>
<td>Simplify your design with highly integrated system on chip (SoC) ultrasonic transducer drivers and signal conditioners</td>
</tr>
</tbody>
</table>

## Key applications

### Automotive
- Ultrasonic park assist
- Powertrain fluid sensors
- Smart kick-to-open trunk

### Industrial
- Industrial / logistics robots
- Vacuum robots / lawn mowers
- Level transmitter

## Featured products

### PGA460 (Q1), PGA46x, PGA47x
- Ultrasonic Signal Processor and Transducer Driver

### PGA44x
- Ultrasonic AFE

## Links to get started

- Design support
- PGA460 EVM training
- Application notes
- Reference designs
Ultrasonic use-cases in Industrial

Service Robots

Vacuum Robots

Ultrasonic sensors can distinguish between floor types and detect approaching cliffs.

Presence/Proximity Sensing / Industrial Robots

Ultrasonic sensors allow for accurate object detection in factory lines, independent of object color, transparency, and density.

Level Sensing

Improve robustness of system & prevent rust with ultrasonic contactless liquid level sensing technology.

Other applications:
- Parking spot sensors
- Garage gate sensors

Robotic Lawn Mowers / Logistics Robot

Ultrasonic sensors can provide obstacle detection and terrain-type detection by the ability to distinguish between different materials in harsh outdoor environments.

Factory & Building Automation

Floor type detection (PGA460)

Cliff detection (PGA460)

Vehicle detection (PGA460)

Obstacle detection (PGA460)

Terrain Type Detection (PGA460)

Level Sensing Measurement (TDC1000)
Why Measure Temperature?

**Protection**
Instant notification of when a system has crossed a thermal limit to prevent damage or maintain safety

Examples:
- Motor Control
- Lighting & Signage
- USB Chargers
- Batteries Charging
- Perishable Goods
- Computing
- Automotive

**Monitor/Control**
Monitor the temperature of the system and take appropriate action

Examples:
- Optimizing Fan Speed
- HVAC & Thermostats
- Industrial control
- Modulating System Clock Frequency
- Refrigeration

**Calibration**
Compensation for temperature sensitive sensors & applications

Examples:
- Gas & Flow Meters
- CMOS Image Sensors
- LED Color Correction
- Optical & Ultrasonic Position Sensors
- Refrigeration
Temperature & Humidity Sensors
High accuracy, High value, Low Power

Why use TI Temperature sensing?
TI offers the widest breadth of temperature sensors ranging from cost competitive alternatives to NTC thermistors to highly integrated digital temperature sensors capable of exceeding the accuracy of Class AA RTDs.

TI’s Temperature & Humidity monitoring solutions

Analog Output
Highly linear output voltage or current proportional to temperature

Digital Output
Integrated sensor & ADC
Highly programmable across I2C, SPI, UART interfaces

Remote (Multi-channel)
Multi-channel digital temp sensors to measure external PN junction (diodes, BJT, processors, FPGA)

Switch / Thermostat
Simple low power over / under temperature detection with hysteresis. Zero SW

Cable / Probe
Low pin count, compact packages optimized for communicating across cables up to 300M

Humidity
Ultra-low power Integrated temperature & humidity sensors

Key applications

Automotive
- Onboard charging
- Infotainment
- Premium Audio
- Electric power steering

Industrial
- Factory Automation
- Building Automation
- Medical
- Test & Measurement

Featured products

TMP117
+/-0.1°C Digital alternative for RTDs or medical applications

TMP235
Cost effective, low power analog temperature sensor

TMP61
Linear PTC alternative to NTC thermistors

HDC2010
Ultra-compact, low power humidity & temperature sensor

Links to get started

Design support
Precision Labs training
E-Book
Competitor-cross reference

Texas Instruments
Thank you
For more information, visit ti.com/sensors
TMP61: PTC Thermistor
Low cost linear alternative to NTCs or RTDs (Class B / C)

Features

- 10KΩ R25 (Resistance @ 25°C) with 1% tolerance
- Linear Temperature Response: TCR: 6400ppm/°C
- Long term stability: 1 % max drift**

**Accelerated testing: translates to 2.2yrs at 85°C

0402 (DEC)
1.0 x 0.6 mm x 0.45mm

TO-92S (LPG)
4.0 x 3.15 mm
(body size)

Vs NTCs
- Simplifies software linearization
- Greater sensitivity at high temperature
- Lower power

Vs RTD
- Lower cost
- No complex analog front end
- No complicated layout
- Lower power
- Can be configured to match RTD curve

Back
TMP117
Ultra-High Precision Digital Temperature Sensor to replace Class AA RTDs

TMP117 Features

<table>
<thead>
<tr>
<th>TI Part</th>
<th>Accuracy (°C) Full Range</th>
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<tbody>
<tr>
<td>TMP117</td>
<td>±0.1°C @ (-20°C to 50°C)</td>
<td>±0.3°C @ (-55°C to 150°C)</td>
</tr>
<tr>
<td>TMP117N</td>
<td>±0.3°C @ (-55°C to 150°C)</td>
<td></td>
</tr>
</tbody>
</table>

- Integrated ADC with 16-bit resolution (0.0078°C)
- Integrated EEPROM
- Low power: 3.5uA average @ 1 sample / second
- Supply: 1.8V to 5.5V
- I2C / SMBus with Alert

Vs RTD

- No need to factor in additional acquisition error (reference, amp, ADC…)
- No calibration needed
- No complex analog front end (current sources, amplifiers, ADCs)
- No trace resistance matching or kelvin connections
- Tremendously lower power
- Simple to program, no linearization
- Automatic sampling & alert

Example RTD Circuit

TI Part Accuracy (°C) Accuracy
Full Range

Full Range

TMP117 N

±0.1°C @ (-20°C to 50°C) ±0.3°C @ (-55°C to 150°C)

2x2mm QFN

1x1.5mm BGA

Example RTD Circuit

Back
TMP117M
Medical Temperature Sensor

TMP117 Features

- ±0.1°C across full medical temperature range
- Integrated ADC with 16-bit resolution (0.0078°C)
- Integrated EEPROM
- Low power: 3.5uA average @ 1 sample / second
- Supply: 1.8V to 5.5V
- I2C / SMBus with Alert

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<th>Accuracy (°C)</th>
<th>Accuracy Full Range</th>
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</thead>
<tbody>
<tr>
<td>TMP117M</td>
<td>±0.1°C @ (30°C to 45°C)</td>
<td>±0.2°C @ (0°C to 85°C)</td>
</tr>
</tbody>
</table>

Application Notes:
- Design Challenges of Wireless Patient Temperature Monitors
- Layout Considerations for Wearable Temperature Sensing

Reference Design:
- Flexible BLE wearable Patch

Video:
University of California Benioff Children's Hospital

TIDA-01624 Reference design for a flexible skin temperature measurement patch
HDC2010 and HDC2080
Integrated Humidity/Temperature Sensor

Features
- Relative Humidity Range: 0%RH to 100%RH
- Humidity Accuracy [Typical, Max]: ±2%, ±3%
- Temperature Accuracy [Typical, Max]: ±0.2°C, ±0.4°C
- Operating Voltage Range: 1.62V to 3.60V
- Operating Temperature Range: -40°C to +125°C
- Interface: I²C
- Typical Active I_DD: 650 µA
- Typical Averaged I_DD (1 measurement/second): 0.55 µA
- Sleep Mode I_DD [Typical, Max]: 50 nA, 100 nA
- Programmable Sample/Acquisition Rate: Various
- Interrupt/Alert Pin with programmable trigger
- Package (HDC2010): 1.5mm x 1.5mm WCSP-6
- Package (HDC2080): 3.0mm x 3.0mm WDFN-6

Applications
- Smart Thermostats, Room Monitors
- IoT
- HVAC
- White goods (dryer, fridge, microwave, dishwasher)
- Printers

Benefits
- Wide supply range for battery power application without LDO/Boost Converter
- Sub 1 µA power consumption is optimal for coin cell operation
- P2P with HDC1010 and HDC1080, and preferred/recommended (for operating voltage range of 1.62V – 3.60V) due to guaranteed humidity tolerance of ±3%RH max

Back
INA190
High Accuracy, Bidirectional, Low- and High-Side, Current-Shunt Monitor with picoAmp Bias Current and Enable Option

Features
- Common Mode Voltage Range: -0.1V to 40V
- High Accuracy
  - Voltage offset: +/-15uV (0.13uV/C)
  - 0.3% gain error (max over temp)
- Low power
  - Low quiescent current @ 25C (65uA max)
  - Low disable current (0.1uA max)
  - Low bias current (500pA typ)
- Five gain options 25, 50, 100, 200 500 V/V
- Independent Supply Voltage of 1.7V to 5.5V
- Temp Range: -40 to 125C
- AEC-Q100 options for 2019 (SC70 Package)

Benefits
- Common mode range supports low- and high-side up to 40V applications
- Smaller error margins needed in design
- Ideal for low power and space sensitive applications
- Small bias current allows for measurement of small µA currents
- Independent supply voltage enables device to interface with 1.8V ADC

Applications
- Notebook Computers
- Cell Phones
- Battery-powered devices
- Telecom Equipment
- Power Management
- Battery Chargers

Tools & Resources
- INA190EVM
- PSpice Model
- TINA-TI Reference Design
- TINA-TI Spice Model
- TI Designs Pending

Back
**Features**
- Common Mode Voltage Range:
  - -0.1V to 40V
- High Accuracy
  - Voltage offset: +/-15uV (0.13uV/C)
  - 0.3% gain error (max over temp)
  - 25V/V, 50V/V, 100V/V, 200V/V, 5000 V/V
- Low power
  - Low quiescent current (70uA max)
  - Low disable current (0.1uA typ)
  - Low bias current (500pA typ)
- Independent Supply Voltage of +1.7V to +5.5V
- Temp Range: -40 to 125°C

**Benefits**
- Common mode range supports low- and high-side up to 40V applications
- Smaller error margins needed in design
- Ideal for low power and space sensitive applications
- Small bias current allows for measurement of small µA currents
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**Applications**
- Notebook Computers
- Cell Phones
- Battery-powered devices
- Telecom Equipment
- Power Management
- Battery Chargers

**Tools & Resources**
- INA191EVM
- PSpice Model
- TINA-TI Reference Design
- TINA-TI Spice Model
- TI Designs Pending

**WCSP**
(1.2 mm x 0.8 mm)
**INA186**

**40V Bidirectional, Low- and High-Side, Current-Shunt Monitor with PicoAmp Bias Current and Enable Option**

### Features
- **Common Mode Voltage Range:**
  - Survivability from -0.3V to 42V
  - Performance specified from -0.1V to 40V
- **Low power**
  - Low quiescent current (70μA max)
  - Low disable current (0.1μA typ)
  - Low bias current (500pA typ)
- **Accuracy**
  - Voltage offset: +/-50μV (0.50µV/C)
  - 1.0% gain error (max over temp)
- **Independent Supply Voltage of +1.7V to +5.5V**
- AEC-Q100 options planned

### Benefits
- Common mode range supports low- and high-side up to 40V applications
- Smaller error margins needed in design
- Ideal for low power and space sensitive applications
- Small bias current allows for measurement of small μA currents
- Independent supply voltage enables device to interface with 1.8V ADC
- Enable pin reduces power consumption (SOT23 package)

### Applications
- Telematics Equipment
- eCall Battery Status
- Battery Management Systems

### Tools & Resources
- INA186EVM
- PSpice Model
- TINA-TI Reference Design
- TINA-TI Spice Model
- TI Designs Pending

**Diagram:**

- Bus Voltage: -0.1 V to 40 V
- Supply Voltage: 1.7 V to 5.5 V
- 0.5 nA (typ) on IN+ and IN-
- 0.1 μF capacitor
- ADC connected to Microcontroller

**SC70-6**

(2.0 mm x 2.1 mm)
INA185
26V, Bidirectional, Low-/High-Side, Current Sense Amplifier, in Industry’s smallest leaded SOT563 package

Features

- Integrated Gain-setting Resistors
- Multiple Gain Offerings V/V: 20 (A1), 50 (A2), 100 (A3), 200 (A4)
- Exceptional performance for the value
  - Max Gain Error: 0.3%, -40°C to 125°C (All variants)
  - CMRR: 100 dB Minimum, 120 dB (typ) (A2-A4 devices)
  - Max Input $V_{DS}$ @ $V_{CM} = 0$ V: 60µV / 0.5µV/°C drift (A2-A4 devices)
  - Max Input $V_{DS}$ @ $V_{CM} = 12$ V: 100µV / 0.5µV/°C drift (A2-A4 devices)
- Wide Bandwidth and High Slew Rate
  - Slew Rate: 2 V/µs
  - BW = 210kHz @ Gain=50
- Ultra-small 1.6mm x 1.6mm SOT563 package

Benefits

- Integrated gain-setting resistors enable the use of small shunt resistances
  - Enhances power efficiency without sacrificing measurement accuracy
- Multiple gain options conveniently scales input signals to match output voltage requirements
- Bi-directional capability simplifies circuit design by reducing the number of external components
- High bandwidth and slew rate allow for reliable measurements in fast switching applications

Applications

- Notebooks
- Telecom
- Solar Inverters
- Power Supply
- Test equipment
- Servers

Tools & Resources

- INA185EVM
- PSpice Model
- TINA-TI Reference Design
- TINA-TI Spice Model
- TI Designs Pending

Back
## INA381 Family

Cost-effective Current Sense Amplifier with Integrated Over-current Comparator

### Features
- Current Sense Amplifier with Integrated Standalone Comparator
- Wide common-mode input voltage range: -0.3 V to 26 V
- **Total (amplifier & comparator) over-current response time:** ≤5us
  - 500ns fast comparator with built in hysteresis
- High Accuracy, High-speed performance
  - $V_{OS} = 500 \mu V$ & $V_{OS}$ Drift = 0.5 µV/°C
  - Gain Error = 1% & Gain Error Drift = 20 ppm/°C
  - 350 kHz Signal Bandwidth (Gain = 20)
- Two Package Options
  - DFN-8 (2x2)
  - MSOP-10 (3x5)

### Benefits
- High Integration and ease of use
- Fast OC protection
- Allows for wide power supply range protection
- Delivers high-precision DC measurements across temperature

### Applications
- Power Delivery Systems
- Battery Management
- Power Windows
- Servers
- Computers
- Power Tools

### Tools & Resources
- INA381EVM
- TINA-TI Spice Model
- TINA-TI Reference Design
- PSpice Model

![INA381 Block Diagram](image)
INA253 High-Voltage, Enhanced PWM Rejection Current Sense Amplifier w/ Precision Integrated Low-Inductive 2mΩ Internal Shunt

Features

- Precision Integrated Shunt Resistor
  - 0.1% Integrated 2mΩ Shunt Resistor with 15ppm/°C across full temperature range
  - Low-inductance 3nH Shunt
  - Up to ±15A @ -40°C to 85°C
  - Kelvin connection guaranteed
- High Accuracy (Current Sense Amplifier and Shunt Resistor)
  - Input Offset Current: 12.5mA (Max) & Offset Drift: 125µA/°C (Max)
  - Gain Error: ±0.5% (Max) & Gain Drift: 25ppm/°C (Max)
  - High AC CMRR: 93dB @ 50kHz
- Wide Common-Mode: -4V to 80V
- Package: TSSOP-20

• **AEC Q100 Option planned in 2018**

Benefits

- High accuracy minimizes system margins and potentially eliminates system-level calibration
- High CMRR allows for direct in-line motor current sensing
- Low inductance reduces PWM spikes and improves measurement accuracy
- Simplifies system design allowing for faster time to market

Applications

- Solenoid/Valve Control
- Motor Control
- Pressure Regulator
- Power Management

Tools & Resources

- INA253EVM
- PSpice Model
- TINA-TI Spice Model
- TI Designs Pending

Back
INA260  Current, Power Monitor with I2C Compatible Interface and Integrated 2mΩ Internal Shunt

**Features**
- Up to +/-15A @ -40°C to 85°C
- 0.1% Integrated 2mΩ Shunt Resistor
- -0.3 to +36V Common-Mode Range
- High Accuracy
  - ±0.5% Gain + Shunt Tolerance Max Over Full -40°C to 125°C Temperature Range
  - 5mA Maximum Offset Current
  - 250μA/°C Maximum Offset Drift
- Application Configurable
  - Reports Current, Voltage and Power
  - Programmable Alert

**Benefits**
- Complete current sense solution
  - Measures up to 10A over full temp range
  - Smaller and more accurate than external shunt resistor, amplifier and ADC
  - Precision integrated shunt resistor offers unmatched system accuracy
- Accurate power monitoring at low current with wide dynamic range for high peak currents
- Adaptable configuration to optimize performance under multiple operating conditions

**Applications**
- Server
- Battery Chargers
- Computing
- Power Supply
- Telecom
- Test equipment

Package: TSSOP-16 (5 x 6.5mm)
Key Hall-effect Products

1st Generation

DRV5012
Low-Power, Low-Voltage Switch
- Low-Power operation:
  - 1.6µA @ 20Hz
  - 153µA @ 2.5kHz
- Low-Voltage operation:
  - 2.5V or 5.5V

DRV5013
High-BW Latch
- 4 Magnet Threshold Options
  - 3.4mT, 5mT, 8mT, 11mT
- 30kHz BW

DRV5011
Smallest Latch in the Industry
- 2mT magnetic sensitivity
- 30kHz BW
- Tiny package options:
  - 1 x 1.1 mm X2SON
  - 0.8 x 0.8 mm DSBGA

2nd Generation

DRV5053
High-Voltage Linear
- 30kHz Signal Bandwidth
- Multiple Sensitivity Options
  - -11mV/mT, -23mV/mT, -45mV/mT, -90mV/mT, +22mV/mT

DRV5056
Ratiometric Unipolar Linear
- 20kHz Signal Bandwidth
- Multiple Sensitivity Options:
  - 25mV/mT, 50mV/mT, 100mV/mT, 200mV/mT
- 5% Sensitivity Accuracy
- 0.12%/°C Magnet Temp Compensation

High Voltage: Up To 38V Supply Voltage

Automotive Grade Available
DRV5032 Family
Ultra-Low-Power Digital Hall Effect Switch

Features
- Industry-leading ultra-low power consumption
  - 5Hz version: 0.54µA with 1.8V
  - 20Hz versions: 1.6µA with 3V
- 1.65V to 5.5V operating supply voltage
- Magnetic threshold options (over temp):
  - FA, FB, FC, FD: 1.5 to 4.8mT, high sensitivity
  - DU: 1.2 to 3.9mT, high sensitivity
  - AJ: 4 to 9.5mT, medium sensitivity
  - ZE: 33 to 63mT, low sensitivity
- Omnipolar or unipolar magnetic response
- Push-pull or open-drain output options
- SOT-23, Ultra-small 1.1 x 1.4 x 0.37mm X2SON package
- -40°C to 85°C operating temperature range

Benefits
- Low power consumption maximizes battery life
- Voltage range compatible with many battery types and traditional MCUs
- Various threshold options prevent false-positives due to interfering magnetic fields
- Numerous magnetic response options allows for flexibility in system design and BOM selections
- Push-pull output removes the need and power drain of an external pullup resistor
- Extremely small and thin X2SON package option for space constrained applications
- Highly reliable magnetic sensor that’s immune to wear, environmental contaminants, dirt, and RF noise versus mechanical switches

Applications
- Battery-critical position sensing
- E-meter tamper detection
- E-locks, smoke detectors
- IoT, medical devices
- Phone, laptop, tablet case sensing

Tools & Resources
- TI Designs
- TechNotes
- DRV5032-SOLAR-EVM

Ultra-Low-Power Digital Hall Effect Switch

Benefits
- Low power consumption maximizes battery life
- Voltage range compatible with many battery types and traditional MCUs
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- Highly reliable magnetic sensor that’s immune to wear, environmental contaminants, dirt, and RF noise versus mechanical switches
DRV5011 Family
Low-Voltage Digital Hall Effect Latch

**Features**
- 2.5V to 5.5V operating supply voltage
- SOT-23 1.1 x 1.4 x 0.37 mm X2SON or 0.8 x 0.8 mm WCSP
- Push-pull output driver
  - 5mA source capability
  - 20mA sink capability
- High magnetic sensitivity: 2mT typical B<sub>op</sub>
- 30kHz bandwidth
- -40°C to 135°C temp range (125°C for WCSP)

**Applications**
- BLDC Motor Sensors
- Incremental rotary encoding
  - Motor Speed
  - Mechanical travel
  - Fluid measurement
  - Wheel speed
- Flat motors
- Power Tools

**Tools & Resources**
- TI Designs
- TechNotes
- DRV5011-5012EVM

**Benefits**
- Voltage range compatible with many battery types and traditional MCUs
- X2SON package enhances design flexibility within compact motors.
- Driver output eliminates the need for an external pullup resistor
- High sensitivity reduces magnet cost and increases sensing distance
- Fast sampling enables use in high-rpm BLDC motors.
- Consistent performance across wide temperature range
- Highly reliable magnetic sensor that’s immune to wear, environmental contaminants, dirt, and RF noise versus mechanical switches

**Back**
### DRV5055 & DRV5055-Q1 Family

#### Ratiometric Linear Hall Effect Sensor

**Features**
- Operating supply voltages of **3V–3.6V** and **4.5V–5.5V**
- Flexible magnetic sensitivity options (at 5V):
  - 12.5 mV/mT (±171 mT range)
  - 25 mV/mT (±86 mT range)
  - 50 mV/mT (±43 mT range)
  - 100 mV/mT (±22 mT range)
- ±5% sensitivity accuracy at 25°C
- Low ±10 mV output noise (50 mV/mT version)
- 0.12 %/°C magnet temperature compensation
- -40°C to 150°C **AEC-Q100 Grade 0** temperature range

**Applications**
- Automotive position sensing
- Brake, acceleration, clutch pedals
- Gear shifters and transmission
- Torque sensor
- Industrial automation and robotics

**Tools & Resources**
- TI Designs
- TechNotes
- DRV505xEVM

**Benefits**
- Voltage range compatible with many battery types and traditional MCUs
- Comprehensive range of magnetic sensitivity options
- Enables precise system measurement
- Ratiometric output eliminates error due to VCC
- Eliminates error due to magnet shifting over temperature
- Suitable for the harshest automotive Grade 0 environments
### Application Example: Angular Measurement

\[ \phi = \tan^{-1} \left( \frac{y \times SENS_{err}(y)) \pm Boff(y) \pm NRMS(y)}{(x \times SENS_{err}(x)) \pm Boff(x) \pm NRMS(x)} \right) \]

<table>
<thead>
<tr>
<th>Resolution, Range</th>
<th>12-bit, ±50mT</th>
<th>14-bit, ±100mT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput/ 2-Axis</td>
<td>20Kbps</td>
<td>1.25Kbps</td>
</tr>
<tr>
<td>( N_{RMS} )</td>
<td>75uT</td>
<td>25uT</td>
</tr>
<tr>
<td>( B_{off} ) Drift</td>
<td>±0.2mT</td>
<td>±0.2mT</td>
</tr>
<tr>
<td>Average Power @ 100Hz</td>
<td>40uA</td>
<td>320uA</td>
</tr>
<tr>
<td>Average Power @ 10Hz</td>
<td>6uA</td>
<td>35uA</td>
</tr>
<tr>
<td>Angular Accuracy @ 360deg rotation</td>
<td>0.5-1deg</td>
<td>0.1-0.5deg</td>
</tr>
</tbody>
</table>
# INA293

-4V/100V High Voltage, High Bandwidth, Unidirectional Current Sense Amplifier

## Features

- **-4V to 100V Common-Mode Range**
  - **-20V to 120V Survivability**
- **Gain options**: 20V/V, 50V/V, 100V/V, 200 V/V, 500V/V
- **DC Accuracy**:
  - Offset: 100µV (MAX) with 1µV/°C drift
  - Gain Error: 0.25% (MAX) with 10 ppm/°C
- **High Speed**: 1MHz -3dB bandwidth and 3V/µs slew rate
- **DC Supply**:
  - 2.7V to 20V
  - IQ: < 1.4 mA
- Available in two pin-out configurations
- **AEC Q100 Option Planned**

## Benefits

- Wide common mode range supports 12V, 24V, 48V, 60V, 72V rails
- -20V negative common mode survivability supports large inductive kick backs.
- Multiple Gain options increase design flexibility
- **Low-side or high-side current sensing**
- High Bandwidth supports lower blanking time for PWM current measurements
- High Slew rate supports for detecting fast over current surges
- Low offset and Low gain error improves system accuracy and enables accurate lower current measurements

## Applications

- 48V Automotive
- Solenoid Control
- 48V Server
- 48V Telecom
- 60V Industrial Auto Transport
- PLC Digital Output Control

## Tools & Resources

- PSpice Models
- TINA-TI Spice Models
- TINA-TI Reference Designs

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**COMING SOON**

**Back**
# TMCS1100

## AC & DC Bi-Directional, Hall-Effect Current Sensor

### Features

- **1% Accuracy (-40 to 125°C)**
- ±600 V Working Voltage, 3 kV Dielectric Isolation (IEC 60950-1)
- Operating voltage: 3.0 V to 5.5 V
- 20 A max continuous DC/RMS current (thermally limited)
- Multiple sensitivities for wide linear measurement ranges
  - TMCS1100A1: 50 mV/A
  - TMCS1100A2: 100 mV/A
  - TMCS1100A3: 200 mV/A
  - TMCS1100A4: 400 mV/A
- 125 kHz signal bandwidth
- 8-pin SOIC package
- **AEC-Q100 Qualified Device Planned (Grade 1)**

### Applications

- Motor Control
- PV String Inverters
- Switching Converters
- Overcurrent Protection
- Power Monitoring
- On-Board Charger PFC

### Tools & Resources

- TMCS1100EVM coming soon
- TINA TI SPICE Model

### Benefits

- Highest accuracy Hall current sensing device in the industry
- Highest working voltage isolation (600 V) in 8-pin SOIC
- Ability to precisely set the reference voltage (V<sub>REF</sub>) independent of V<sub>CC</sub> enables higher accuracy.
- V<sub>REF</sub> can be shared with ADC for increased system accuracy.
- Fixed sensitivity eliminates ratiometry errors and improves supply noise rejection
- Ability to measure an isolated AC or DC current
- In-package sensing simplifies PCB and application design

---

**IN+**

**IN-**

**Hall Element**

**Bias**

**Temperature Compensation**

**Offset Cancellation**

**Output Amplifier**

**Reference Sampling**

**V<sub>REF</sub>**

**V<sub>VS</sub>**

**V<sub>GND</sub>**

**V<sub>OUT</sub>**

**TMCS1100**

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Samples: July 2019
Release: 4Q19
**TMCS1101**

AC & DC Bi-Directional, Hall-Effect Current Sensor

### Features
- **1.5% Accuracy (-40 to 125°C)**
- ±600 V Working Voltage, 3 kV Dielectric Isolation (IEC 60950-1)
- Operating voltage: 3.0 V to 5.5 V
- Bi-direction and uni-directional variants
- 20 A max continuous DC/RMS current (thermally limited)
- Multiple sensitivities for wide linear measurement ranges
  - TMCS1101AB/U1: 50mV/A
  - TMCS1101AB/U2: 100mV/A
  - TMCS1101AB/U3: 200mV/A
  - TMCS1101AB/U4: 400mV/A
- 125 kHz signal bandwidth
- 8-pin SOIC package
- **AEC-Q100 Qualified Device Planned (Grade 1)**

### Benefits
- **Board drop-in for any SOIC-8 Allegro ACS71X or ACS72X device**
- High accuracy current sensing for precision measurements
- Highest working voltage isolation (600V) in 8-pin SOIC
- Fast response time for switching power supplies and in-line motor applications
- Internally generated reference voltage for bi-directional or uni-directional current sensing
- Ability to measure an isolated ac or dc current
- In-package sensing simplifies PCB design

### Applications
- Motor Control
- PV String Inverters
- Switching Converters
- Overcurrent Protection
- Power Monitoring

### Tools & Resources
- **TMCS1101EVM** coming soon

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**Samples: July 2019 Release: 4Q19**
TMCS Ambient Current Sensing

- Magnetic field strength proportional to current through trace or bus bar
- Beside The Trace Sensing
  - Device axis of sensitivity is orthogonal to plane of package
  - Simplifies mechanical implementation
- Magnetic core or shielding can be designed to concentrate flux or reduce stray fields
Ultrasonic Backup
## Relevant Tools & Resources

Get started with TI’s ultrasonic sensing technology

### App Notes
- PGA460 Full-Bridge Driver Solutions for Ultrasonic Transducers
- PGA460 Software Development Guide (Rev. A)
- PGA460 Frequently Asked Questions (FAQ) and EVM Troubleshooting Guide
- PGA460 Ultrasonic Module Hardware and Software Optimization

### E2E/Blog Posts
- Use Ultrasonic sensing for graceful robots
- Where are ultrasonic sensors used? – Part 1
- Where are ultrasonic sensors used? – Part 2
- How ultrasonic technology improves convenience and performance in home automation
- Everything You Need to Know for Ultrasonic ToF (Air-Coupled)

### Videos
- Ultrasonic Sensing with the PGA460-Q1
- Ultrasonic Sensing Training Series
- PGA460 ultrasonic sensing: EVM hardware, transducer, and driver selection

### TI Designs/EVMs
- PGA460-Q1 EVM With Transducers
- Ultrasonic Distance Sensor with IO-Link Reference Design

Visit: [ti.com/ultrasonic](https://ti.com/ultrasonic)
PGA460
Ultrasonic transducer driver and signal conditioner (ASSP solution)

Integration

Advanced DSP core integrated for echo detection (signal conditioning, time of flight measurement).

Integrated temp sensor (-40 to 125°C) with an accuracy of 5°C.

Diagnostics
- Monitor transducer voltage during burst
- Frequency and decay time of transducer
- Supply-side and transceiver-side diagnostics for overvoltage, undervoltage, overcurrent and short-circuit scenarios

Flexibility

Time-command interface (TCI) or one-wire USART asynchronous interface (IO pin) or a CMOS-level USART interface (RXD, TXD pins) available.

Two presets for both bursting and thresholds available which allow faster detection cycles by saving time required to configure device between multiple bursts.

Most configuration parameters are stored in nonvolatile memory for quick power up, which reduces initialization time.

Ultra-low quiescent current low-power mode to reduce power consumption when not in use.

Signal Conditioning

Analog front-end (AFE) consisting of a low-noise amplifier followed by a programmable time-varying gain stage feeding into an ADC enabling distance detection as low as 10cm to 11m.

Wide dynamic range of gain amplifier (32dB to 90dB) allows for both near-field and far-field object detection in the same recording.

12 point time-varying thresholding allowing for flexibility in noise rejection.

PGA460EVM GUI
(Time-varying gain & threshold)

DSP Path

Received ultrasonic echo
Gain
Threshold
### Features

- **Distance:** 20cm – 5m (automotive ISO pole); 5cm – 11m (non-auto)
- **Transducer Frequency:** 30kHz – 80kHz, 180kHz - 480kHz
- **Wide Dynamic Analog Gain:** 32dB to 90dB
- **Wide Transformer current drive:** 30mA - 500mA
- **Integrated Accurate Temperature Sensor:** (<± 5°C error)
- **Interface:** 1-Wire UART or Time Command Interface (TCI)
- **Operating Temperature:** -40 to 105 °C
- **Package:** 16-pin TSSOP

### Benefits

- Suitable to use for Industrial market, requirements of 20cm – 5m+ detection which optimized to detect objects in ranges most frequently specified by drone and robotics applications
- Flexible transducer frequency range allows for the device to drive and receive with a wide range of transducers
- Flexible state machine which can be easily configured via EEPROM. And No MCU code and debug required.
- Industry leading cost competitiveness

### Applications

- Robotics Collision Avoidance and Position Sensing
- Robotics/Drone Obstacle Detection and Landing Assist
- Occupancy and Motion Sensors
- Ultrasonic Radar

### Tools & Resources

- PGA460 Datasheet
- PGA460 EVM Training Video Series
- PGA460 Schematic and Layout examples
- BOOSTXL-PGA460EVM
- TIDA-01386 : Ultrasonic Distance Sensor with IO-Link Reference Design