



TEXAS INSTRUMENTS

Webinar

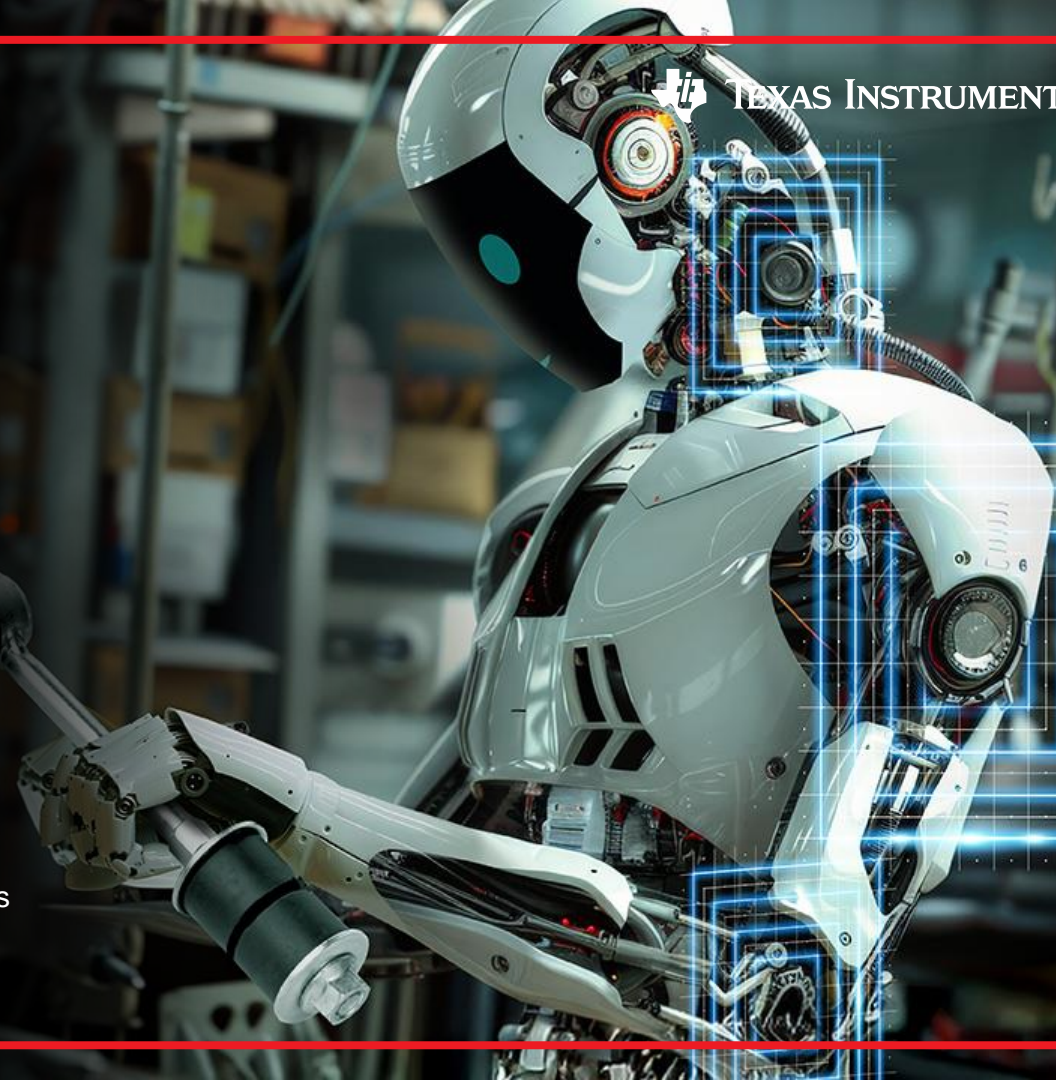
Enhancing motor control in robotics with functionally isolated current sensing technology

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Agenda

- Functional isolation overview
- Amplifier vs. modulator comparison
- Shunt based current sensing
- Differential vs. Ratiometric Outputs
- AMC01xx and AMC21Cxx use cases
- Functional isolation selection guide
- Getting started resources

Introduction

Market trend

Growing investments centered around the integration of robotics into everyday life to aid humans.

Market need

More precise, efficient, size-optimized and cost-effective isolated voltage and current sensing.

Our Solution

New portfolio of functionally isolated current and voltage sensing amplifiers and modulators as well as comparators designed to improve accuracy at a reduced solution size and cost.



Functional isolation

Functional isolation

- Galvanically isolated amplifiers and modulators for voltage and current sensing in $\leq 200 V_{\text{RMS}}$ motor drives, power delivery systems, industrial PLCs and I/O modules
- Analog and digital output options
 - Amplifiers with differential or single-ended output
 - Modulators with 10MHz or 20MHz, external clock
- Supports up to $200 V_{\text{RMS}}$ working voltage at PDII
 - No agency certification (no UL or VDE certification)
- Primary benefits
 - High common-mode transient immunity (CMTI)
 - Smallest solution size
 - 2.7 x 3.7 mm leadless package for industrial applications
 - Cost optimized solution

Functional isolation | Target applications

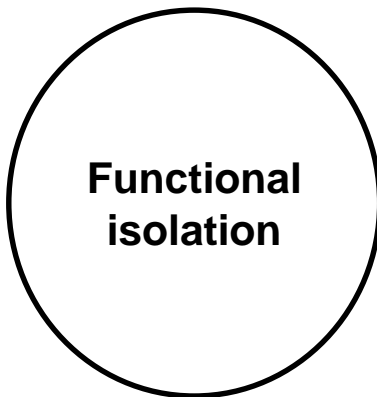
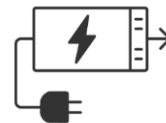


FA&C

- Robotics
- PLC, DCS & PAC
 - Industrial I/O

Power delivery

- Rack & server power
- Telecom power
- Industrial power



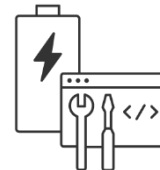
Industrial transport

- E-bike
- E-scooter
- Off-highway vehicle



Appliances

- Power tools
- Vacuum cleaner
- Battery packs



Medical

- Surgical equipment
- Ultrasound scanner
- CPAP



Grid infrastructure

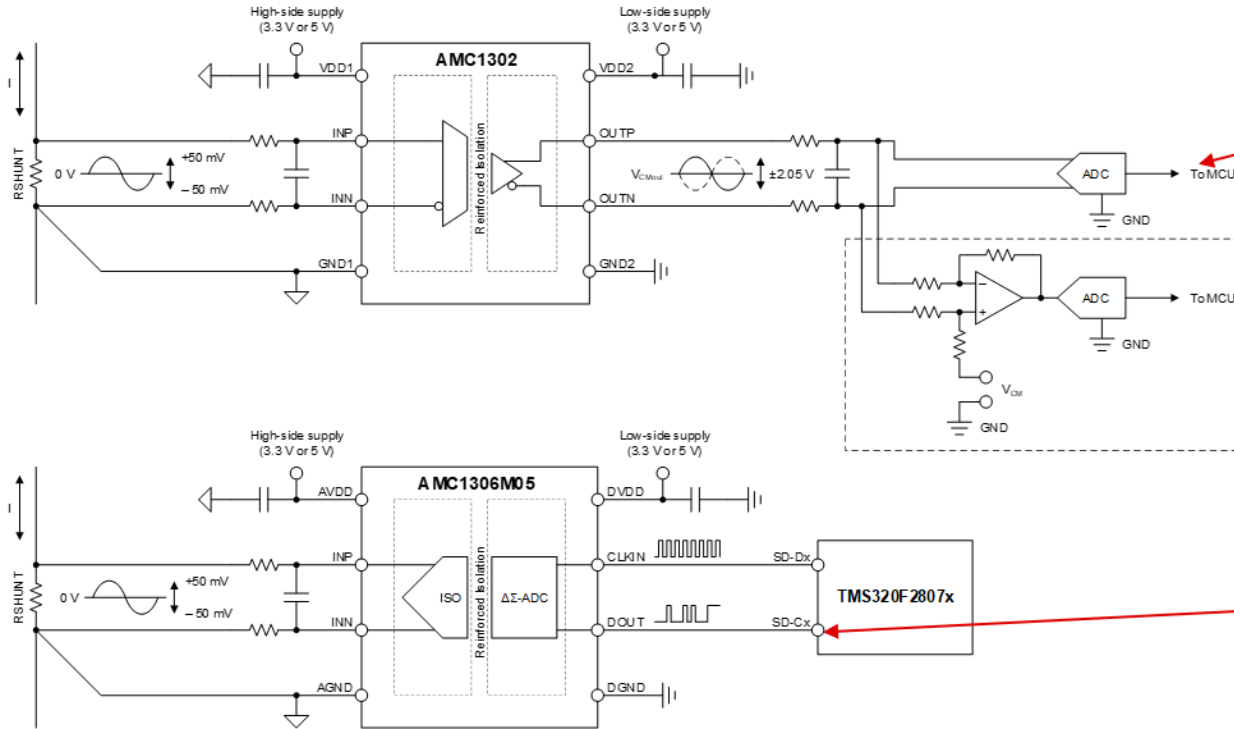
- Solar energy
- Energy storage
- Smart meter

Motor drives

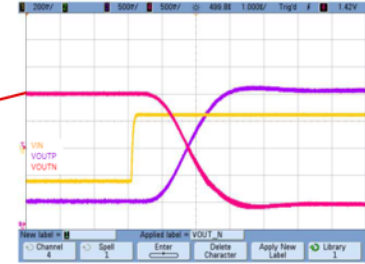
- Drones
- Stepper drives



Isolated sensing | Amplifiers vs modulators



Amplifier Analog Output



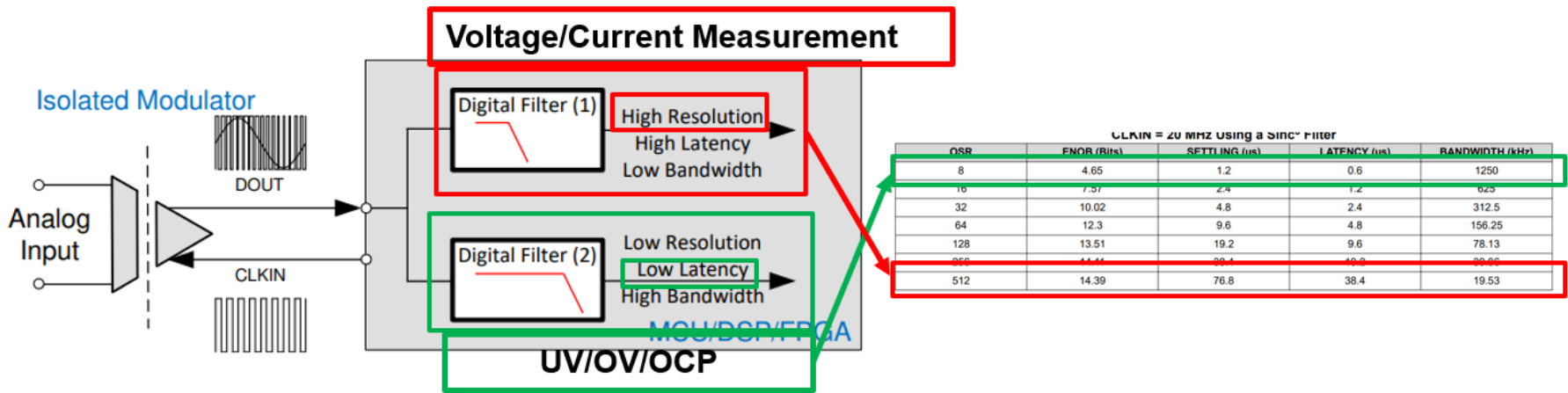
Modulator Digital Output



Isolated sensing | Amplifiers vs modulators

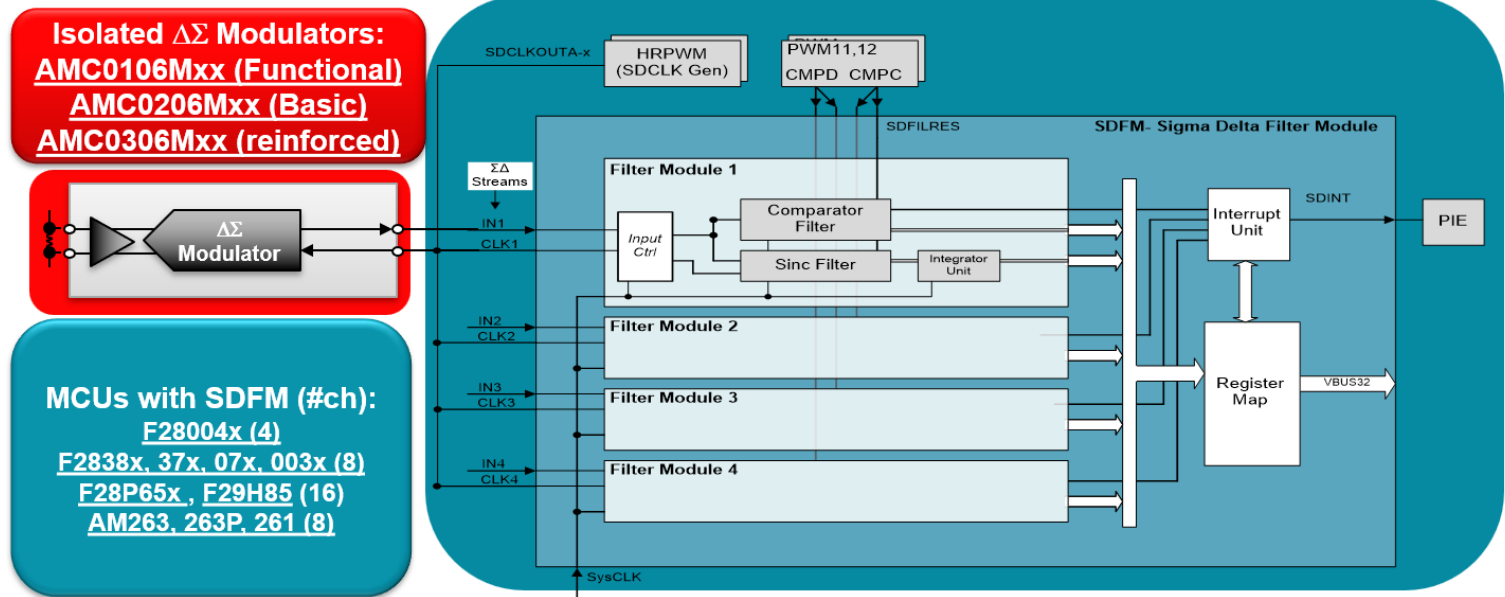
Table 3-1. Performance Comparison Between Isolated Amplifiers and Isolated Modulators

CATEGORY	ISOLATED AMPLIFIER	ISOLATED MODULATOR
Sample resolution	11 bits (bandwidth = 100 kHz)	> 14 bits achievable, trade-off between resolution and bandwidth or latency
Latency	2 μ s to 3 μ s (fixed)	< 1 μ s achievable, trade-off between resolution and bandwidth or latency
Bandwidth	up to 300 kHz	> 1 MHz achievable, trade-off between resolution and bandwidth or latency
Accuracy and drift performance	High	Very high
No. of components needed	More	Less



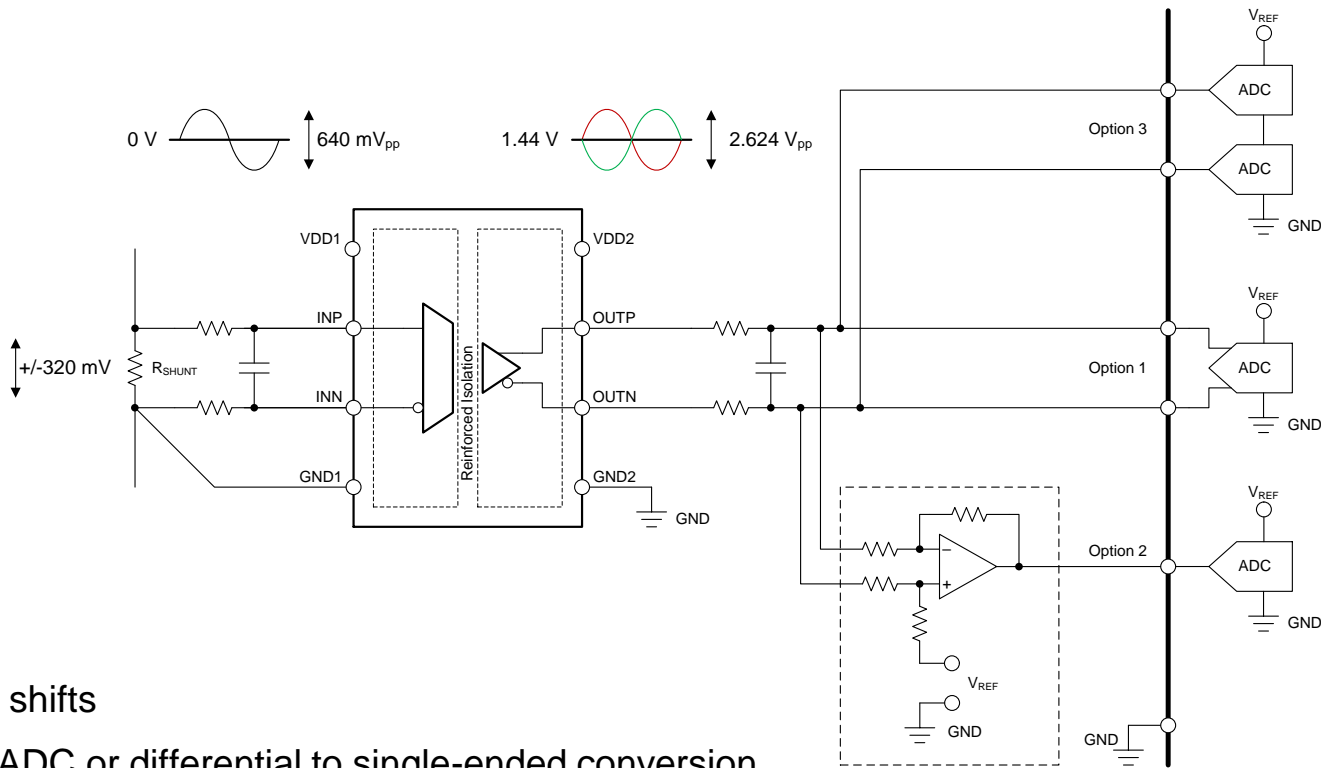
Isolated sensing | Amplifiers vs modulators

Real-time Control MCU with Filters for $\Delta\Sigma$ Modulators



Differential vs. Ratiometric output

Existing Solution: Differential Analog Output



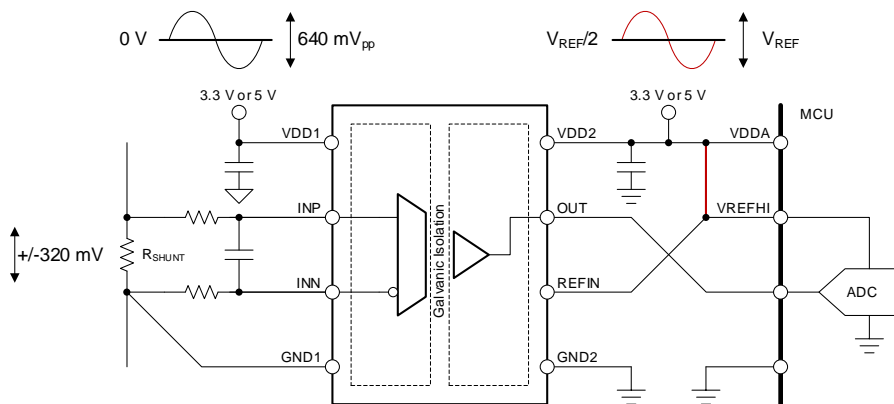
- ▲ Highest accuracy
- ▲ High noise immunity
- ▲ Insensitive to ground shifts
- ▼ Requires differential ADC or differential to single-ended conversion

SE Output for AC Current Sensing

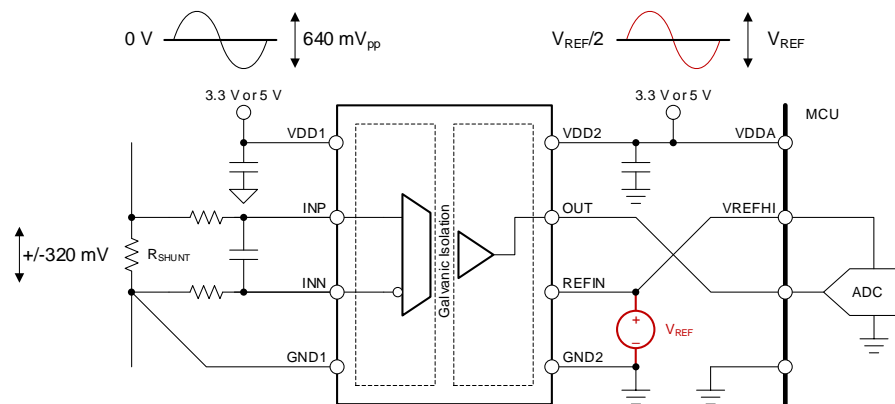
Single-Ended Outputs | Ratiometric

- Output Of Amplifier: $V_{OUT} = (V_{INP} - V_{INN}) / 320 \text{ mV} \times (V_{REF} / 2) + (V_{REF} / 2)$
- Supported V_{REF} range : 2.7..5.5 V
- Input voltage range: $\pm 250 \text{ mV}$ (linear), $\pm 320 \text{ mV}$ (clipping),

Low-cost: V_{REF} derived from supply

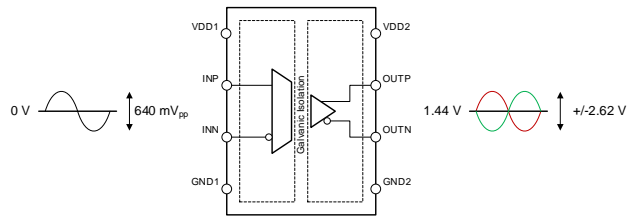


Low Noise: V_{REF} supplied by external reference

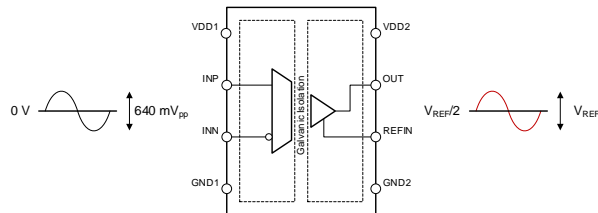


Diff vs SE Output | ± 250 mV Current Measurement

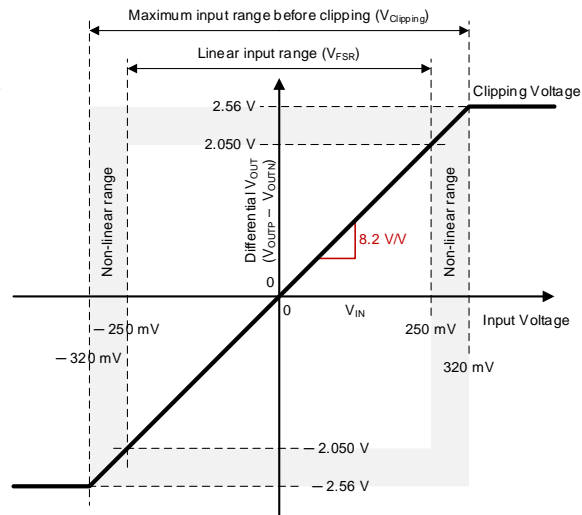
Differential Output



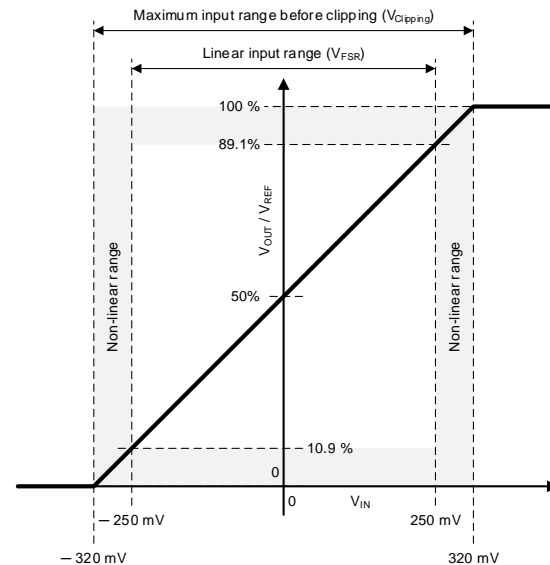
Ratiometric SE-Output



Differential Output



Single-Ended Output

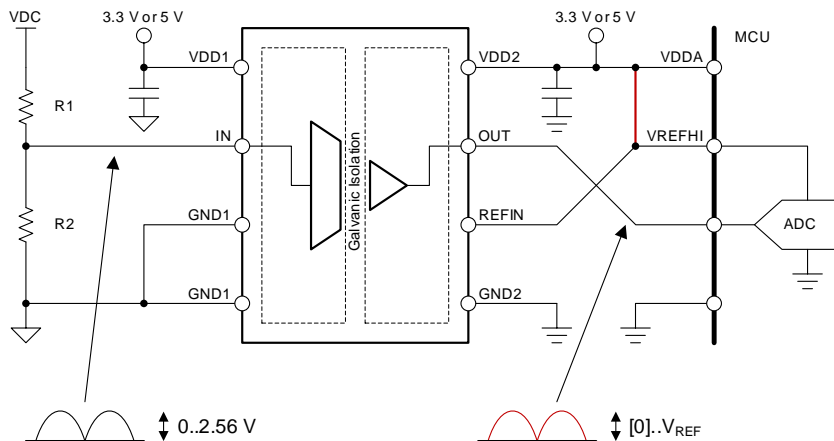


SE Output for DC Voltage Sensing

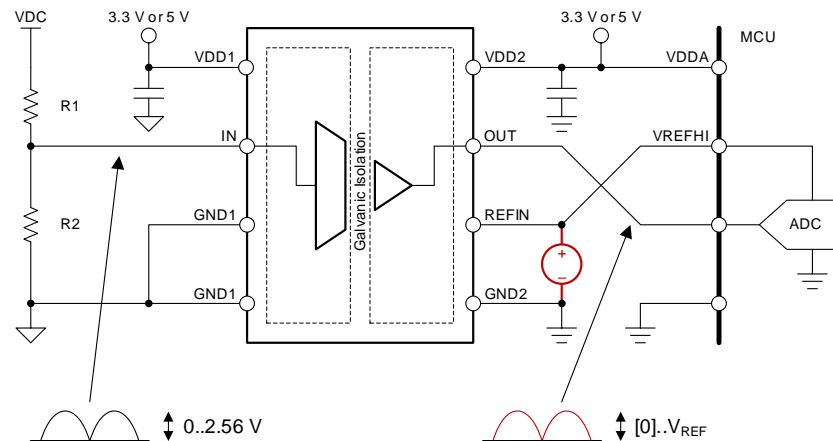
Single-Ended Outputs | Ratiometric

- Output Of Amplifier: $V_{OUT} = V_{IN} / 2.56 \text{ V} \times V_{REF}$
- Supported V_{REF} range : 2.7..5.5 V
- Input voltage range: 0.25 to 2 V (linear), 0 to 2.56 V (clipping)

Low-cost: V_{REF} derived from supply

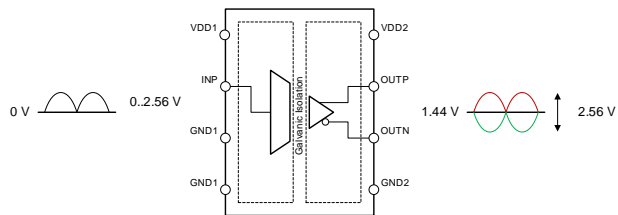


Low Noise: V_{REF} supplied by external reference

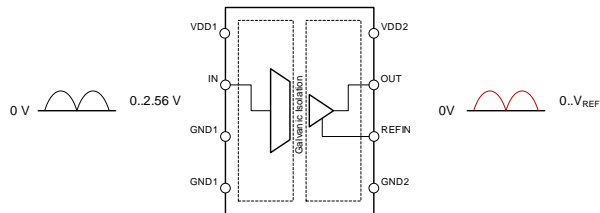


Diff vs SE Output | 2-V DC Voltage Measurement

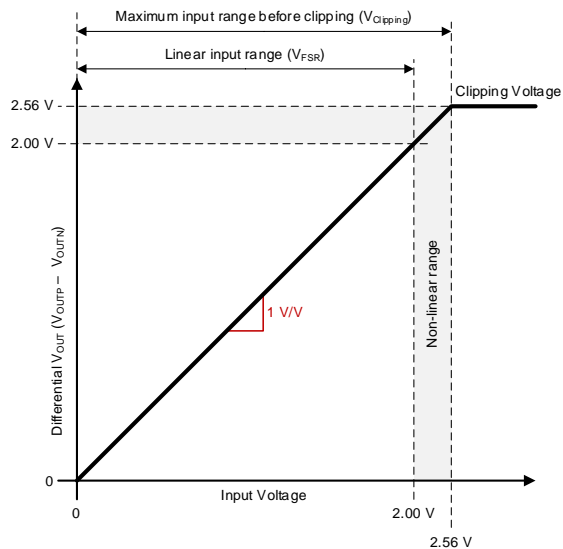
Differential Output



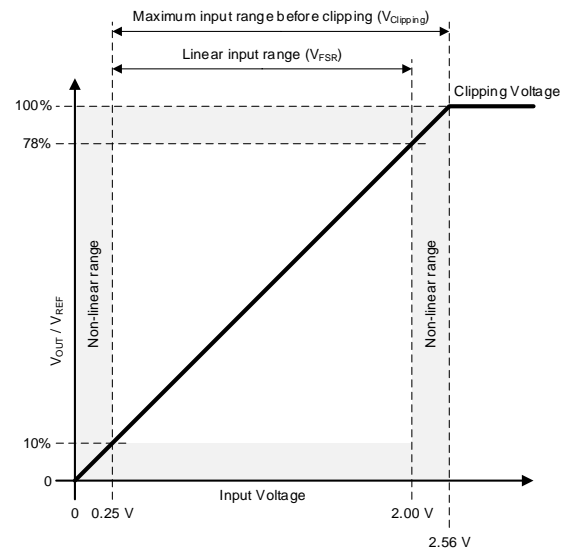
Ratiometric SE-Output



Differential Output

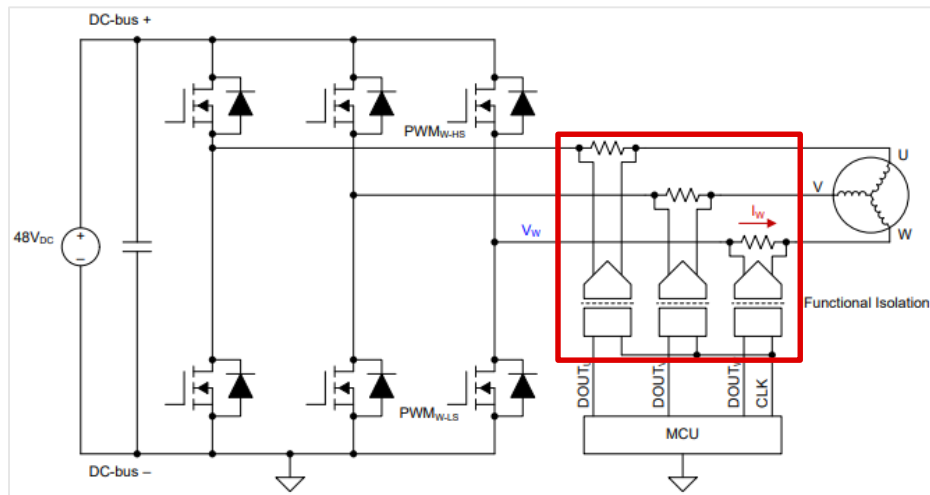


Single-Ended Output



Isolated sensing | Shunt-based current sensing

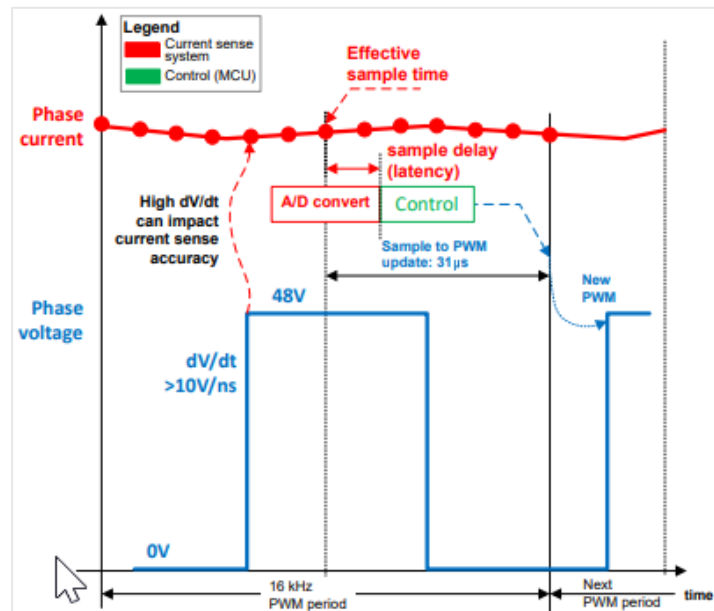
- In-phase current sensing enables higher performance, continuous measurement, and more precise control of the motor phase current over the entire PWM cycle compared to low-side shunt sensing.
 - This is the most common choice in servo drives and robotics
- Small form factor as well as low height are critical requirements for space-constrained customer applications
 - Competition includes in-package hall sensors as well as shunts working alongside non-iso amps
 - Shunt-Based current sensing with delta-sigma modulator provides the highest measurement resolution
 - Most common choice in high-performance motor drives



Robotics | 48V low voltage servo/robotics

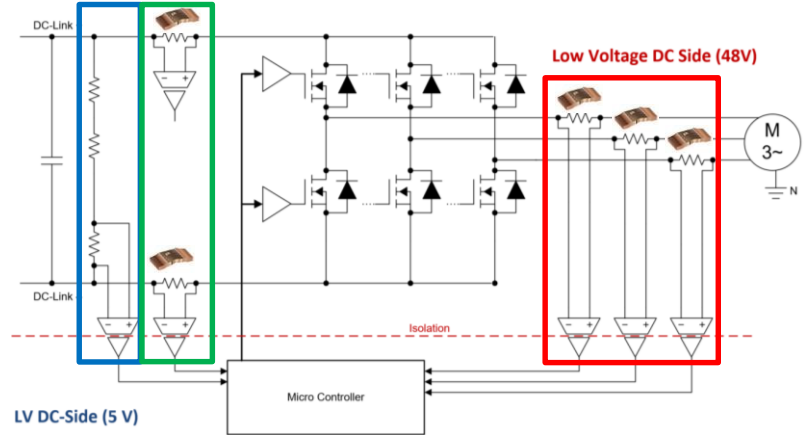
- System requirements include:

- High accuracy
 - Better than 1%
- High resolution
 - > 12 effective number of bits
- Low propagation delay
 - < 20us latency
- High common-mode voltage
 - > 60V
- High CMTI
 - >> 10V/ns
- Fast short-circuit detection
 - < 2us
- High immunity to interferences and magnetic fields
- Small size and low cost

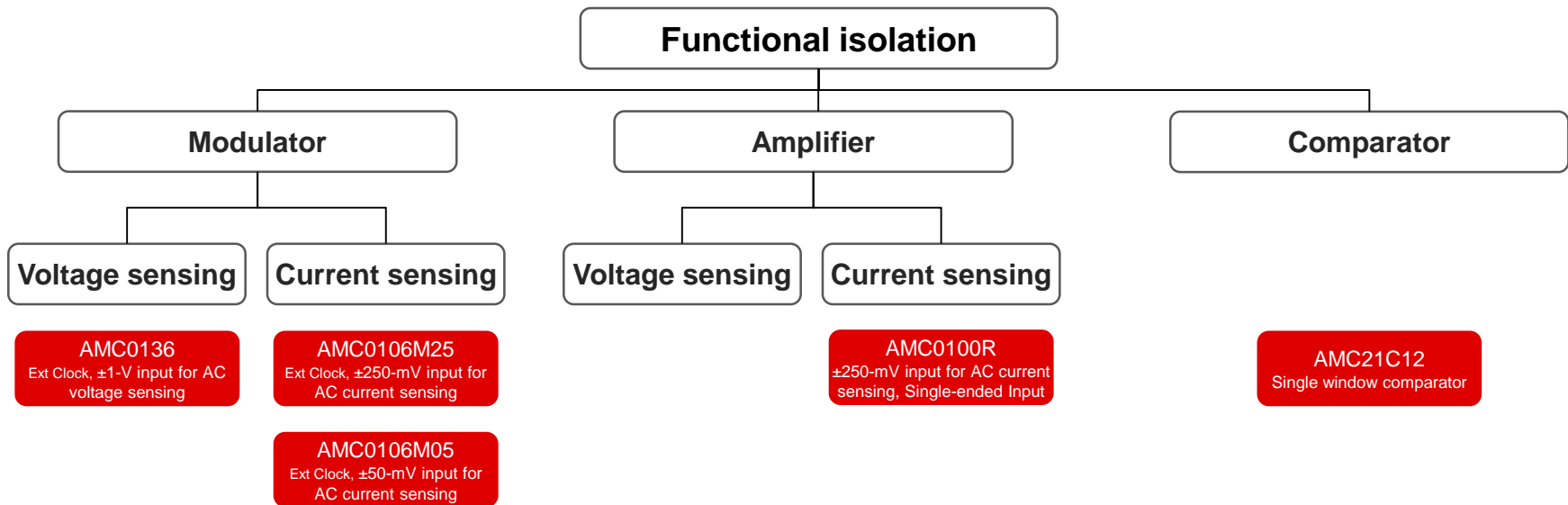


Robotics | 48V low voltage servo/robotics

- DC voltage sensing
 - AMC0136 isolated modulator
- AC current sensing
 - AMC0100 isolated amplifier
 - AMC0106M05/25 isolated modulator
- Over-Current Detection
 - AMC21C12



Functional isolation | Portfolio overview



VIOWM / BW / CMTI

Available now

VIOWM / BW / CMTI

In development

Functionally isolated amplifiers

AMC0100R

±250-mV Input Functionally Isolated Amplifier w/ Single-Ended Output for Current Sensing

Features

Isolation	Functional	AC Current Sensing
Voltage Input Range	±250 mV	Functional Isolation
Input Offset / Drift (max)	±0.2 mV / ±1 μ V/°C	High Accuracy
Gain Error / Drift (max)	±0.3% / ±40 ppm/°C	Single-Ended Output
Nonlinearity (max)	±0.03%	Supports 2.7 V to 5.5 V Reference Voltages
Output BW (typ)	300 kHz	Small Package
Working Voltage (V_{IOWM})	800 V _{RMS} (basic) 1.5 kV _{RMS} (reinforced)	
Withstand Voltage (V_{ISO})	3 kV _{RMS} (basic) 5 kV _{RMS} (reinforced)	
CMTI (min)	150 V/ns	
Temperature Range	-40°C to 125°C	

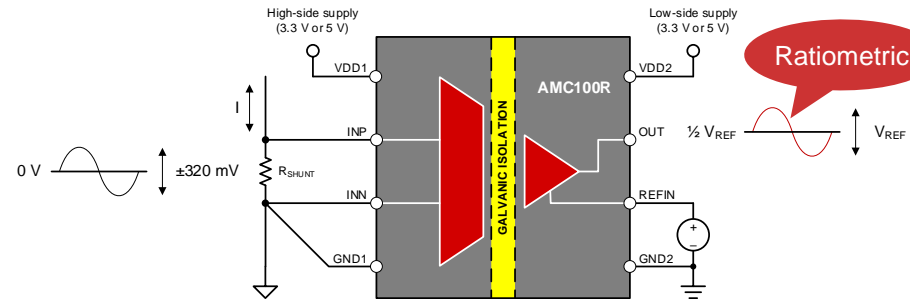
Applications

Isolated AC Current Sensing in:

- Industrial Motor Drives
- Photovoltaic Inverter
- Uninterruptible Power Supplies
- Power Factor Correction
- On-Board Chargers (OBC)
- DC/DC Converters
- Frequency Inverters

Benefits

- ±250-mV Input optimized for current sensing
- Low offset and gain errors & drift for **highest accuracy**
- Single-ended analog output for **smallest solution size** and **lowest BOM cost**
- Small package** for space constrained applications



DEN (2.7 mm x 3.7 mm)

Functionally isolated modulators

AMC0106M05 / -Q1

±50 mV Input Functionally Isolated Delta-Sigma Modulator for **Current Sensing**

Features

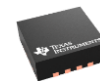
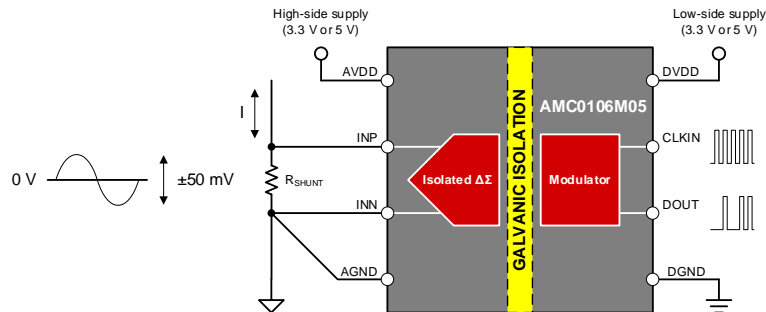
Isolation	Functional	Current Sensing
Lin Input Voltage Range	±50 mV	
Input Offset / Drift (max)	±50 μV / ±1 μV/°C	Functional Isolation
Gain Error / Drift (max)	±0.2% / ±40 ppm/°C	20 MHz External Clock
SNR (typ)	82 dB	
Working Voltage	200 V _{RMS}	High Accuracy
CMTI (min)	100 kV/μs	Small Package
Temperature Range	-40°C to 125°C	

Applications

- **Isolated AC Current Sensing in 48-V systems:**
 - Autonomous guided vehicles & mobile robots (AGV / AMR)
 - Cobots
 - Low-voltage servo drives / BLDC drives
 - Linear Motor Drives
 - DC/DC converters

Benefits

- **±50-mV Input** optimized for current sensing
- Low offset and gain errors & drift for **highest accuracy**
- Galvanic isolation with **high transient immunity**
- **External** clock simplifies synchronization to PWM
- **Small package** for space constrained applications



DEN (2.7 mm x 3.7 mm)

AMC0106M25 / -Q1

±250 mV Input Functionally Isolated Delta-Sigma Modulator for **Current Sensing**

Features

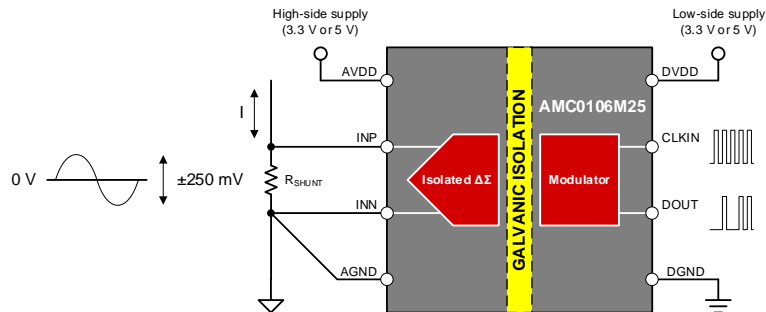
Isolation	Functional	Current Sensing
Lin Input Voltage Range	±250 mV	
Input Offset / Drift (max)	±100 μ V / ±1 μ V/°C	Functional Isolation
Gain Error / Drift (max)	±0.2% / ±40 ppm/°C	20 MHz External Clock
SNR (typ)	86 dB	
Working Voltage	200 V _{RMS}	High Accuracy
CMTI (min)	100 kV/ μ s	Small Package
Temperature Range	-40°C to 125°C	

Applications

- **Isolated AC Current Sensing in 48-V systems:**
 - Autonomous guided vehicles & mobile robots (AGV / AMR)
 - Cobots
 - Low-voltage servo drives / BLDC drives
 - Linear Motor Drives
 - DC/DC converters

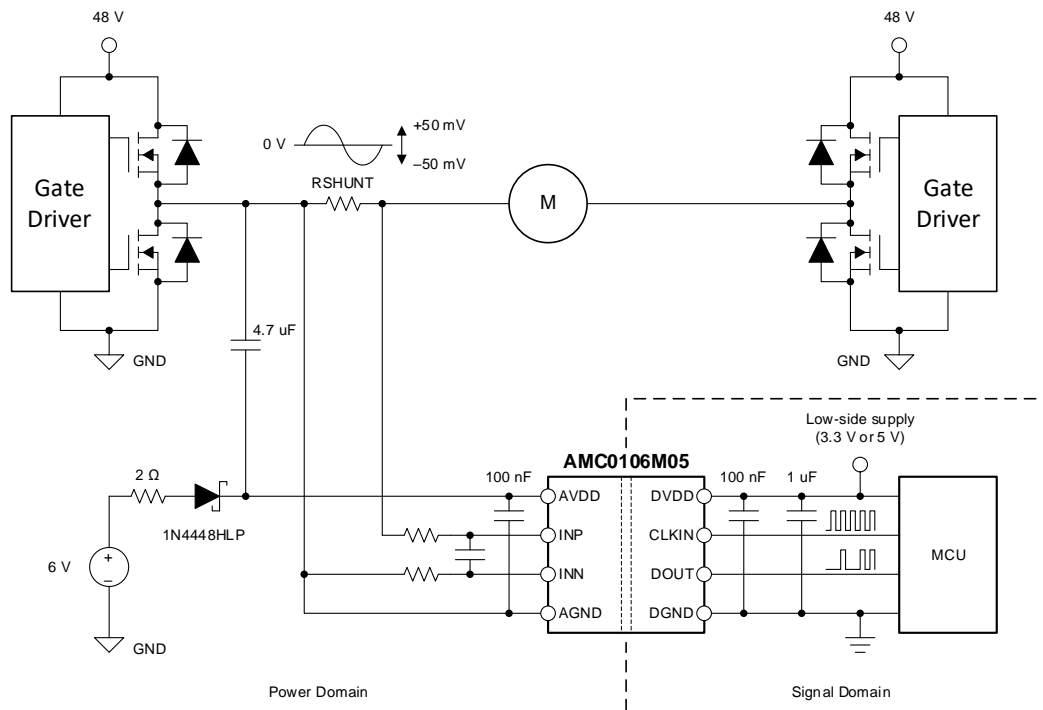
Benefits

- **±250-mV Input** optimized for current sensing
- Low offset and gain errors & drift for **highest accuracy**
- Galvanic isolation with **high transient immunity**
- **External** clock simplifies synchronization to PWM
- **Small package** for space constrained applications



DEN (2.7 mm x 3.7 mm)

Application example | Phase current sensing



AMC0136 / -Q1

±1-V Input Functionally Isolated Modulator for AC Voltage Sensing

Features

Isolation	Functional	AC Voltage Sensing
Lin Input Voltage Range	±1V	
Input Offset / Drift (max)	±0.9mV / ±7μV/°C	Functional Isolation
Gain Error / Drift (max)	±0.25% / ±40 ppm/°C	
Max Clock Frequency	10MHz	High Accuracy
Working Voltage (V_{IOWM})	200V _{RMS}	10 MHz Ext. Clock
CMTI (min)	150V/ns	
Temperature Range	-40°C to 125°C	Small Package

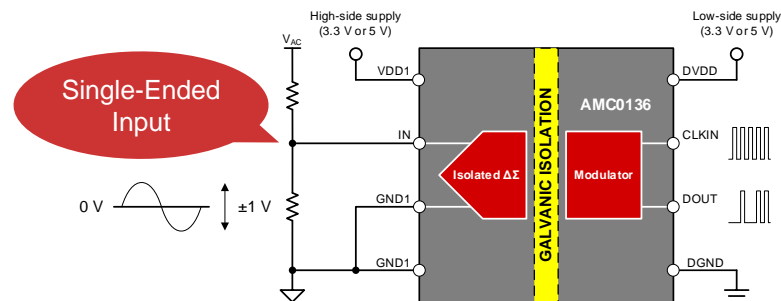
Applications

Isolated AC Voltage Sensing in:

- Industrial Motor Drives
- Photovoltaic Inverter
- Uninterruptible Power Supplies
- Power Factor Correction
- Industrial PLC & I/O modules
- On-Board Chargers (OBC)
- DC/DC Converters
- Frequency Inverters

Benefits

- High Impedance, bipolar Input for **AC Voltage sensing**
- Low offset and gain errors & drift for **highest accuracy**
- External clock** for simplified system level synchronization
- Small package** for space constrained applications



DEN (2.7 mm x 3.7 mm)

Functionally isolated comparators

AMC21C12

Fast Response, Functionally Isolated Window Comparator with Adjustable Threshold and Latch Function

Features

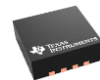
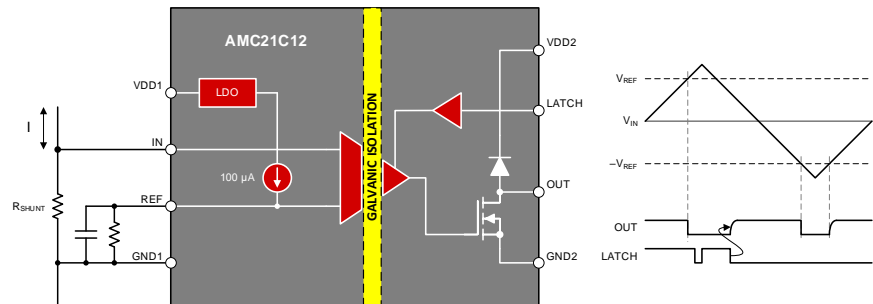
VDD1	3.0 to 27 V	Fast Response
VDD2	3.0 to 5.5 V	Functional Isolation
Trip Threshold	20 mV to 2.7V	Adj. Threshold
Response Time (typ)	290 ns	Open-Drain Output w/ Latch Function
Output	Open-drain	Small Size
Working Voltage	200 V _{RMS}	Low Cost
CMTI (min)	55 kV/ μ s	
Temperature Range	-40°C to 125°C	

Applications

- **Bi-directional phase over-current detection** in
 - Servo Drives
 - AC Inverters
- **Over-voltage detection** in
 - Frequency Inverters
 - Solar Inverters
 - Industrial I/O Modules

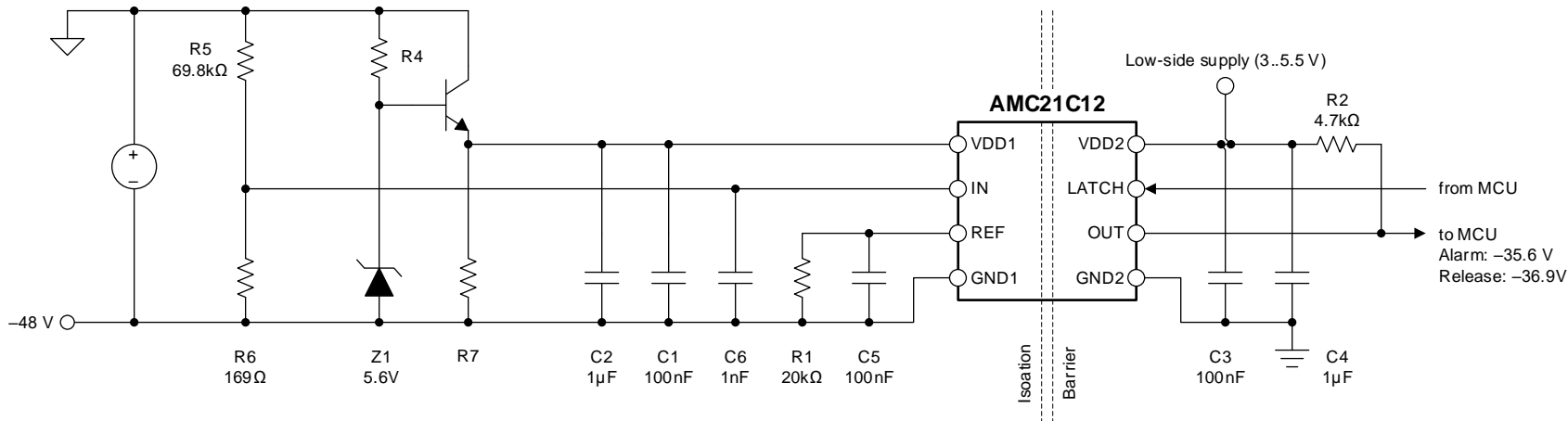
Benefits

- **Fast response time (290 ns, typ)** enables efficient OV/OC protection in fast-switching applications
- Open-drain output with **Latch function** allows periodic polling
- **Smallest solution size on the market** enables higher level of integration, BOM cost reduction, and smaller form factor designs
- **Integrated high-side LDO** for powering from gate-driver supply
- **Easy to use**, trip-point adjustment with single external resistor



DEN (2.7 mm x 3.7 mm)

Application example | -48V monitoring



Getting started with isolated voltage sensing

You can learn more about these devices by leveraging the following:

Content type	Content title	Link to content or more details
White paper	How advanced current and voltage sensing enable ultraprecise robotics	Technical article
Application notes	High resolution, small form factor phase current sense for 48V robotics and servo drives	Application note
	Comparing isolated amplifiers and isolated modulators	Application note
Reference design	48V/16A small form factor three-phase GaN inverter reference design for integrated motor drives	Reference design
Product folders	Amplifier and modulator product folders	AMC0136 , AMC0106M25 , AMC0106M05
	Comparator product folder	AMC21C12



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