Welcome!
Texas Instruments New Product Update

- This webinar will be recorded and available at www.ti.com/npu
- Phone lines are muted
- Please post questions in the chat or contact your TI sales contact or field applications engineer

INDUSTRY'S MOST ACCURATE 110V, BIDIRECTIONAL CURRENT SENSE AMPLIFIERS IN SMALL SOT-23 PACKAGE

New Product Update

Kyle R. Stone
CS Product Marketing Engineer

Agenda

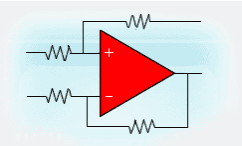
- High-voltage current sense amplifier overview
- Overview of the INA241 & INA296 with comparison
- Industry leading accuracy
- Getting started
- Use-case examples

High CMV (≥48V) Analog Output

Existing | New Release | In Development | Roadmap

Q100 Option Available

Q100 in Development



Low CMV Analog Output | **High CMV Analog Output** | Integrated Comparator(s) | In-Package Shunt Resistor | Digital Monitor

Ultra Precise:
- V_{OS} ≤ 50µV
- Gain Err ≤ 0.3%
- CMRR ≥ 120dB

INA240
–4.0V to 80V CMR
25uV Offset, 0.2% Gain Error
Gains: 20, 50, 100 V/V
Enhanced PWM Rejection
AEC-Q100 Grade 0 in SOIC
TSSOP & SOIC

INA293
-4V to 110V CMR
-20V to 120V Survivability
20µV Offset , 0.15% Gain Error
1.3MHz BW & 2.5V/µs slew rate
Gains: 20, 50, 100, 200, 500V/V
SOT-23 Dual Pinouts

INA290/2290/4290
2.7V to 120V CMR
-20V to 122V Survivability
12µV Offset , 0.1% Gain Error
1.1MHz BW & 3V/µs slew rate
Gains: 20, 50, 100, 200, 500V/V
SC-70 (5) / MSOP (8) / QFN (16)

INA296A
-4V to 110V CMR Bidirectional
-20V to 120V Survivability
12µV Offset , 0.05% Gain Error
1MHz BW & 5V/µs slew rate
Gains: 10, 20, 50, 100, 200 V/V
Multiple package options (SOT23-8)

INA241A
-4V to 110V CMR
-20V to 120V Survivability
12µV Offset , 0.05% Gain Error
Enhanced PWM Rejection
Gains: 10, 20, 50, 100, 200 V/V
Multiple package options (SOT23-8)

High Precision:
- V_{OS} ≤ 500µV
- Gain Err ≤ 1.0%
- CMRR ≥ 90dB

LMP8480 – 8481
4.5V to +76V CMR
265uV Offset , 0.8% Gain Error
Gains: 20, 50, 60, 100V/V
MSOP-8

P2P

INA281
-4V to 110V CMR
-20V to 120V Survivability
150µV Offset , 0.5% Gain Error
1.3MHz BW & 2.5V/µs slew rate
Gains: 20, 50, 100, 200, 500V/V
SOT-23 Dual Pinouts

P2P

INA280
2.7V to 120V CMR
-20V to 122V Survivability
150µV Offset , 0.5% Gain Error
1.1MHz BW & 3V/µs slew rate
Gains: 20, 50, 100, 200, 500V/V
SC-70

P2P

INA296B
-4V to 110V CMR Bidirectional
-20V to 120V Survivability
150µV Offset , 0.1% Gain Error
1MHz BW & 5V/µs slew rate
Gains: 10, 20, 50, 100, 200 V/V
Multiple package options (SOT23-8)

P2P

INA241B
-4V to 110V CMR
-20V to 120V Survivability
150µV Offset , 0.1% Gain Error
Enhanced PWM Rejection
Gains: 10, 20, 50, 100, 200 V/V
Multiple package options (SOT23-8)

General Purpose

INA282 – INA286
-14V to +80V CMR
70uV Offset , 1.4% Gain Error
Gains: 50, 100, 200, 500, 1000
CMRR: 140dB Minimum
SOIC-8 & MSOP-8

P2P

INA193 – INA198
-16V to +80V CMR
2mV Offset , 2.5% Gain Error
Gain Options: 20, 50, 100V/V
SOT-23 Dual Pinouts

INA270 & INA271
-16V to +80V CMR
2.5mV Offset , 2.5% Gain Error
Gain Options: 14, 20V/V
Split Stage for Filtering
SOIC

LMP8601 – 8603
-22V to +60V CMR
1mV Offset , 0.5% Gain Error
Gains: 20, 50, 100V/V
Split Stage for Filtering
AEC-Q100 Grade 0 (Gain=20)
SOIC-8

LMP8640HV
-2V to +76V CMR
900uV Offset, *0.25% Gain Error*
Gains: 20, 50, 100V/V
SOT-23

Current Output: External Gain Resistor

INA168 & INA169
2.7V to +60V CMR
1mV Offset, 2% Gain Error
BW: INA168=800kHz
INA169=440kHz
SOT-23

INA170
2.7V to +60V CMR
1mV Offset , 2% Gain Error
Bidirectional
MSOP

Voltage Output With Adjustable Gain

LMP8645HV
-2V to +76V CMR
External resistor sets gain
900uV Offset,
SOT-23

Texas Instruments

INA241A

-5 to 110V, Bi-directional, Ultra-Precise Current Sense Amplifier w/ Enhanced PWM Rejection

Features

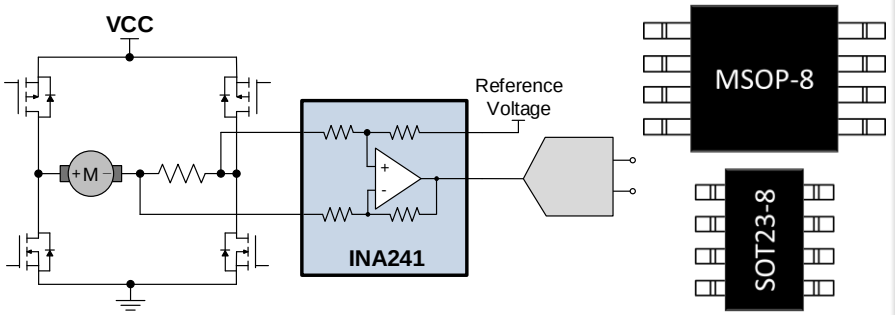
- Enhanced PWM Rejection minimizes output distortion due to high dV/dt common mode transitions
- -5V to 110V Common Mode Voltage
  - -20V to 120V Survivability
- Multiple Gain Options
  - 10V/V, 20V/V, 50V/V , 100V/V and 200V/V
- High Accuracy
  - Common Mode Rejection Ratio (CMRR): 150 dB (Min)
  - Offset: 10 µV (Max) / Offset Drift : 100 nV/°C (Max)
  - Gain Error : 0.01% (Max) / Gain Drift : 1.0 ppm/c (Max)
- AC Specifications:
  - Ideal for up to 100KHz Switching common mode applications
  - 8 V/us Slew rate
- Package options: 8-Pin SOT-23 & 8-pin MSOP

Applications

- EPS
- 48V Servers
- Solenoid Control
- 60V Industrial Auto Transport
- Powertrain engine management
- 3Ph Brushless Motor Control

Benefits

- High CMRR and Enhanced PWM rejection allows for direct in-line motor current sensing
- Supports 12V,24V,48V,60V,72V rails
  - Supports large inductive kick backs.
- High accuracy minimizes system margins
  - Improves measurements over full temperature range
  - Supports smaller shunt values (< 1mΩ)
- Multiple Gain options increase design flexibility



INA241B

-5 to 110V, Bi-directional, Ultra-Precise Current Sense Amplifier w/ Enhanced PWM Rejection

Features

- Enhanced PWM Rejection minimizes output distortion due to high dV/dt common mode transitions
- -5V to 110V Common Mode Voltage
  - -20V to 120V Survivability
- Multiple Gain Options
  - 10V/V, 20V/V, 50V/V , 100V/V and 200V/V
- High Accuracy
  - Common Mode Rejection Ratio (CMRR): 120 dB (Min)
  - Offset: 150 µV (Max) / Offset Drift : 500nV/°C (Max)
  - Gain Error : 0.1% (Max) / Gain Drift : 5.0 ppm/c (Max)
- AC Specifications:
  - Ideal for up to 100KHz Switching common mode applications
  - 8 V/us Slew rate
- Package options: 8-Pin SOT-23 & 8-pin MSOP

Applications

- EPS
- 48V Servers
- Solenoid Control
- 60V Industrial Auto Transport
- Powertrain engine management
- 3Ph Brushless Motor Control

Benefits

- High CMRR and Enhanced PWM rejection allows for direct in-line motor current sensing
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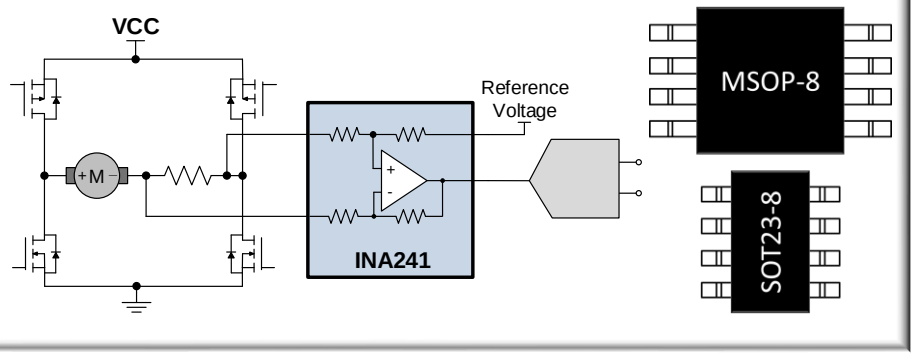
- Multiple Gain options increase design flexibility



INA296A

-5 to 110V, Bi-directional, 1MHz, Ultra-Precise Current Sense Amplifier

Features

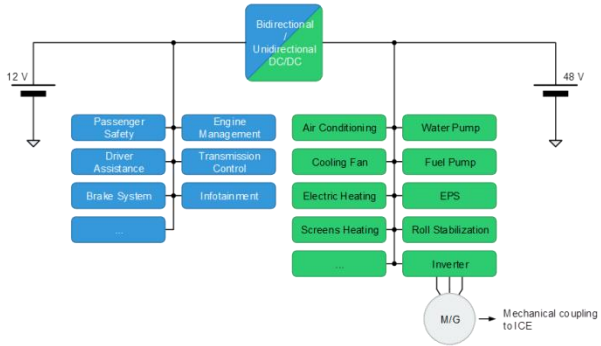
- Wide Common-Mode Voltage Range : -5V to +110V
  - Survivability From -20V to +120V
- High Speed: 1MHz Signal Bandwidth with 5V/µs Slew Rate
- DC Accuracy:
  - Common Mode Rejection Ratio (CMRR): 150 dB (Min)
  - Offset: 10 µV (Max) / Offset Drift : 100 nV/°C (Max)
  - Gain Error : 0.01% (Max) / Gain Drift : 1.0 ppm/c (Max)
- Gain options: 10V/V, 20V/V, 50V/V, 100V/V, 200 V/V
- Slew rate: 8 V/µs
- DC Supply: 2.7V to 20V
- Package options: SOT23-8 & MSOP-8

Applications

- DC/DC Converter
- Network & Server PSU
- Battery Management Systems
- On-Board & Wireless Charger

Benefits

- Supports 12V,24V,48V,60V,72V rails
  - Supports large inductive kick backs.
- High accuracy minimizes system margins
  - Improves measurements over full temperature range
  - Supports smaller shunt values (< 1mΩ)
- High bandwidth and slew rate supports faster signal throughput
  - Ripple current measurement
  - Over-current protection
  - Reduced blanking times in PWM applications
- Multiple Gain options increase design flexibility



INA296B

-5 to 110V, Bi-directional, 1MHz, Ultra-Precise Current Sense Amplifier

Features

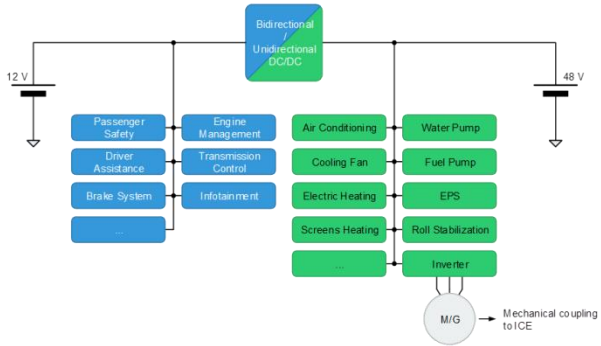
- Wide Common-Mode Voltage Range : -5V to +110V
  - Survivability From -20V to +120V
- High Speed: 1MHz Signal Bandwidth with 5V/µs Slew Rate
- DC Accuracy:
  - Common Mode Rejection Ratio (CMRR): 120 dB (Min)
  - Offset: 150 µV (MAX) with 500 nV/°C drift
  - Gain Error: 0.1% (MAX) with 5 ppm/°C drift
- Gain options: 10V/V, 20V/V, 50V/V, 100V/V, 200 V/V
- Slew rate: 8 V/µs
- DC Supply: 2.7V to 20V
- Package options: SOT23-8 & MSOP-8

Applications

- DC/DC Converter
- Network & Server PSU
- Battery Management Systems
- On-Board & Wireless Charger

Benefits

- Supports 12V,24V,48V,60V,72V rails
  - Supports large inductive kick backs.
- High accuracy minimizes system margins
  - Improves measurements over full temperature range
  - Supports smaller shunt values (< 1mΩ)
- High bandwidth and slew rate supports faster signal throughput
  - Ripple current measurement
  - Over-current protection
  - Reduced blanking times in PWM applications
- Multiple Gain options increase design flexibility



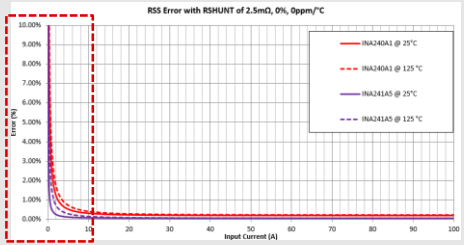
Option Comparison Table

	INA240	INA296A	INA296B	INA241A	INA241B
VCM Spec Range	4V to 80V	-5V to +110V	-5V to +110V	-5V to +110V	-5V to +110V
VCM Abs Max	-6V to +90V	-20V to +120V	-20V to +120V	-20V to +120V	-20V to +120V
Gain Error @ 25C (Max)	0.20%	0.05%	0.10%	0.05%	0.10%
Gain Error Drift (Max)	2.5 ppm/°C	1.0 ppm/°C	5.0 ppm/°C	1.0 ppm/°C	5.0 ppm/°C
Gain Error Over Temp (Max)	0.23%	0.08%	0.15%	0.08%	0.15%
VOS @ 25C (Max)	25 µV	10 µV	150 µV	10 µV	150 µV
VOS Drift (Max)	0.25 µV/°C	0.10 µV/°C	0.5 µV/°C	0.10 µV/°C	0.5 µV/°C
VOS Over Temp (Max)	50µV	20 µV	200 µV	20 µV	200 µV
CMRR (Min)	120dB	150dB	120dB	150dB	120dB
PSRR (Min)	100dB	120dB	100dB	120dB	100dB
VS	2.7V to 5.5V	2.7V to 20V	2.7V to 20V	2.7V to 20V	2.7V to 20V
IQ (Max)	2.6 mA	3 mA	3 mA	3 mA	3 mA
Gain Options	20, 50, 100, 200	10, 20, 50, 100, 200	10, 20, 50, 100, 200	10, 20, 50, 100, 200	10, 20, 50, 100, 200
IB (VCM=12V, VREF=2.5V)	90 µA Typ	30 µA Typ	30 µA Typ	30 µA Typ	30 µA Typ
IB (VCM=48V, VREF=2.5V)	160 µA Typ	30 µA Typ	30 µA Typ	30 µA Typ	30 µA Typ
Bandwidth	100 kHz Signal 400 kHz Switching	1.1 MHz Signal	1.1 MHz Signal	1.1 MHz Signal 125 kHz Switching	1.1 MHz Signal 125 kHz Switching
Slew Rate	2 V/µs	8 V/µs	8 V/µs	8 V/µs	8 V/µs
Swing To Ground	10 mV	20 mV	20 mV	20 mV	20 mV
Temp Range: Grade 1	-40°C to +125°C	-40°C to +125°C	-40°C to +125°C	-40°C to +125°C	-40°C to +125°C
Temp Range: Grade 0	-40°C to +150°C	-40°C to +150°C	-40°C to +150°C	-40°C to +150°C	-40°C to +150°C
Package	HTSSOP-8 SOIC-8	SOT23-8 MSOP-8	SOT23-8 MSOP-8	SOT23-8 MSOP-8	SOT23-8 MSOP-8

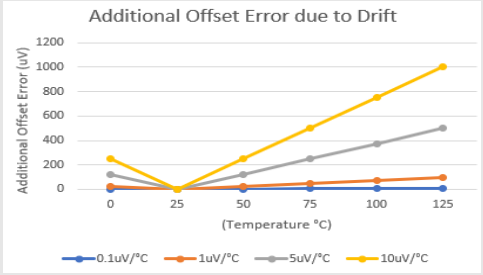
Industry Leading Accuracy

TI Current Sensing – Current Sense Amplifiers

Offset voltage as low as 10µV

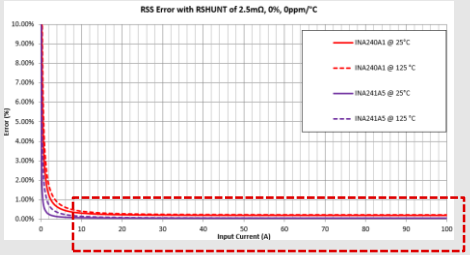


Offset drift as low as 0.1µV/°C (max)



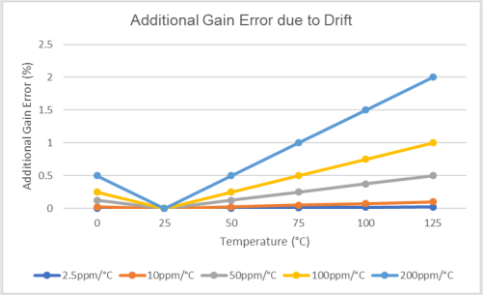
Zero drift architecture enables low offset error and low offset drift, helping with low-current measurements (without needing to calibrate)

Gain error as low as 0.01%



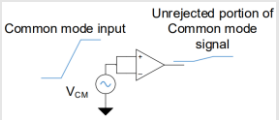
Low gain error helps with full scale current measurements

Gain error drift as low as 1.0 ppm/°C



CMRR as high as 166dB (DC), 104dB (AC)

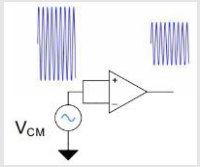
166dB DC CMRR



DC CMRR enables accurate measurements in HV systems

INA296A

104dB AC CMRR

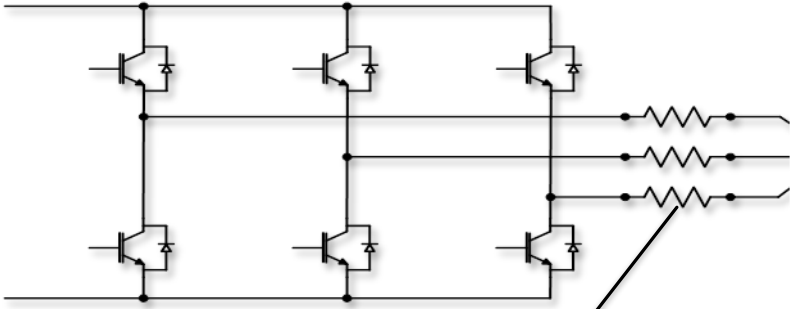


AC CMRR reduces need for filtering for all frequency Vcm noise

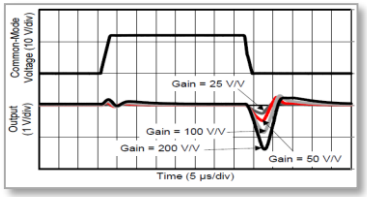
INA296A

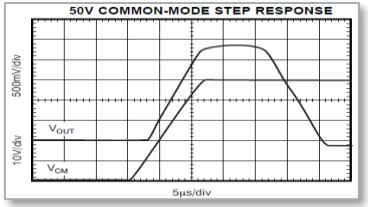
CMRR relates to the stability of the output with respect to input (reducing output noise + additional offset)

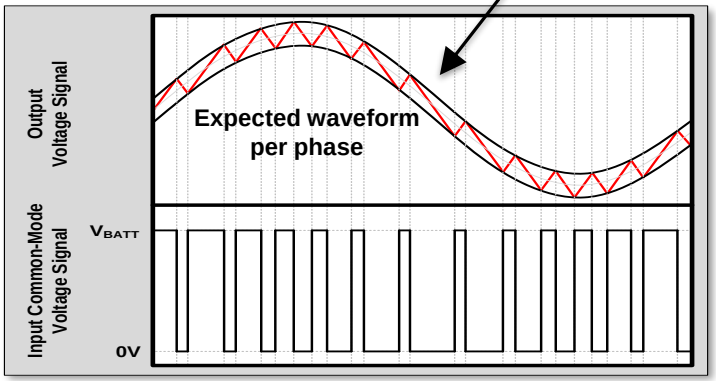
In-Line Motor Current Sensing: Harsh current measurement environment



Large common-mode steps induce large output disturbance





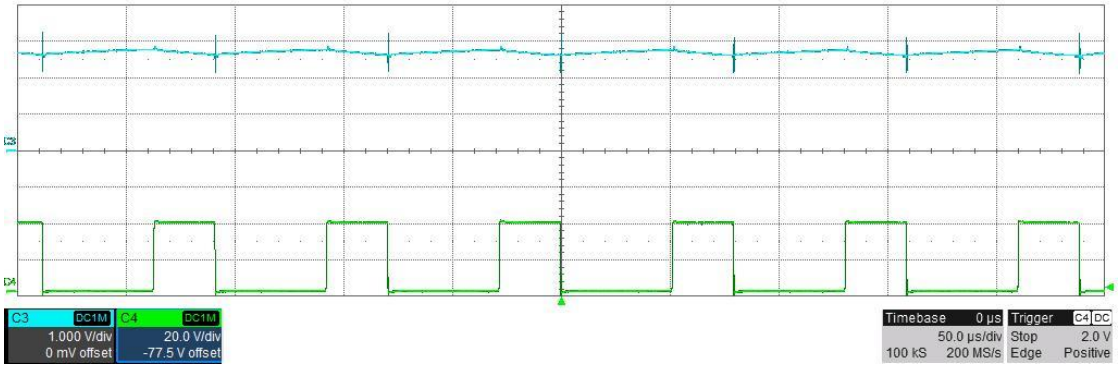


How to make precision shunt measurements on large common-mode voltage transitions

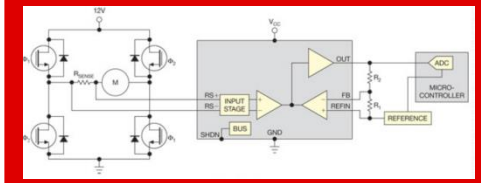
- Current measurement for applications employing PWM control method for transistor drive circuitry used in motor and solenoid control
- Be able to reject input common-mode step voltages of PWM control method as high as 100V/10ns with minimal observable output glitch
- Operate over a wide common-mode voltage range including below ground to accommodate flyback period of typical solenoid application

The tale of a competitor… it is not a trivial task!

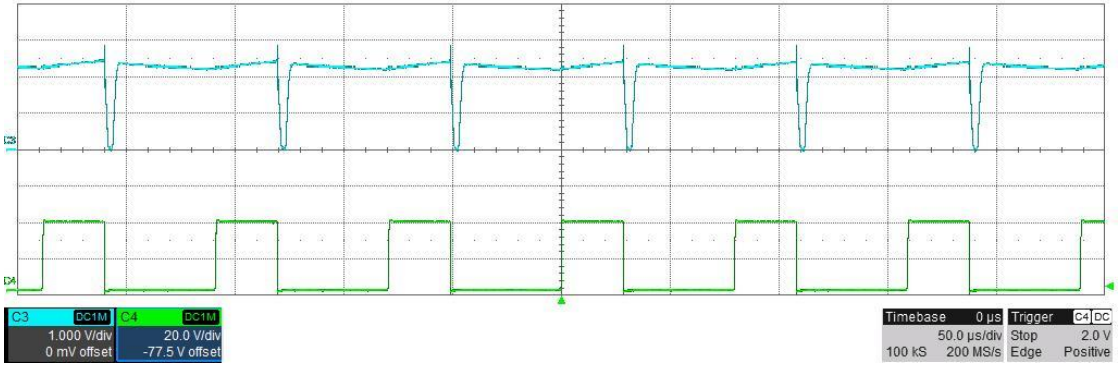
How the phase current should look



How this competitor looks



Competitor Paper:
http://www.edn.com/design/analog/4369564/Monitor-PWM-load-current-with-a-high-side-current-sense-amplifier



Getting started

You can start evaluating this device leveraging the following:

Content type	Content title	Link to content or more details
Product folder	INA241A, INA241B, INA296A, INA296B	https://www.ti.com/product/INA241A https://www.ti.com/product/INA241B https://www.ti.com/product/INA296A https://www.ti.com/product/INA296B
Reference design	INA240 reference designs – Note the INA241 can replaced INA240 in these reference designs	https://www.ti.com/reference-designs/index.html#search?keyword=ina240&famid=57,3170
Analog Design Journal	Second-sourcing options for small-package amplifiers	https://www.ti.com/lit/an/slyt744/slyt744.pdf
Models	PSpice Model are available	See product folder links above
Evaluation Module	INA241AEVM INA296AEVM	https://www.ti.com/tool/INA241AEVM https://www.ti.com/tool/INA296AEVM

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