Zero-Drift, Precision Current Sense Amplifier

Features

- Offset Voltage: ±250 µV (MAX)
- Wide Common-Mode Voltage: 2.7 V to 30 V
- Accuracy and Zero-Drift Performance
- ±1% Gain Error (Max over temperature)
- 0.5µV/°C Offset Drift (Max)
- 10 ppm/°C Gain Drift (Max)
- Four Gain Options:
  - TPA183A1: 25 V/V
  - TPA183A2: 50 V/V
  - TPA183A3: 100 V/V
  - TPA183A4: 200 V/V
- Quiescent Current (IN+): 220 µA (Maximum)
- Rail-to-Rail Output
- Package: SOT23-5
- Industrial −40°C to 125°C Operation Range
- ESD Rating: Robust 2 kV – HBM, 2 kV – CDM

Applications

- Current Sense (High−Side/Low−Side)
- Power Management
- Battery Chargers

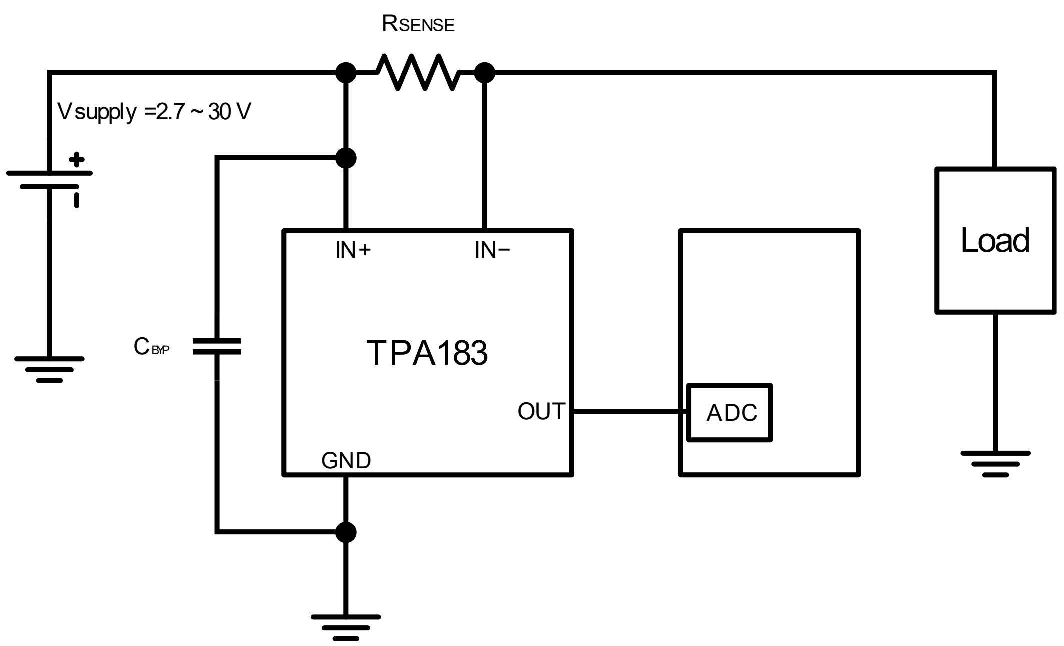
Description

The TPA183 series of zero-drift, unidirectional current sense amplifiers can sense voltage drops across shunts at common-mode voltages from 2.7 V to 30 V. The TPA183 series supports a voltage output with options of four fixed gains: 25 V/V, 50 V/V, 100 V/V, and 200 V/V. The low offset of the zero-drift architecture enables current sensing with maximum drops across the shunt as low as 10 mV full-scale.

The TPA183 does not have a separate V_{CC} supply voltage pin. The operating supply voltage is internally connected to IN+ pin, drawing a maximum of 220 µA quiescent current.

All versions are specified from –40°C +125°C and offered in the SOT23-5 package.

Typical Application Circuit



Product Family Table

Order Number	Gain (V/V)	Package	Transport Media, Quantity	Package Marking
TPA183A1-S5TR	25	SOT23-5	Tape and Reel, 3,000	3A1
TPA183A2-S5TR	50	SOT23-5	Tape and Reel, 3,000	3A2
TPA183A3-S5TR [Note 1]	100	SOT23-5	Tape and Reel, 3,000	3A3
TPA183A4-S5TR [Note 1]	200	SOT23-5	Tape and Reel, 3,000	3A4

Note 1: For future products, contact the 3PEAK factory for more information and sample.

Table of Contents

Revision History

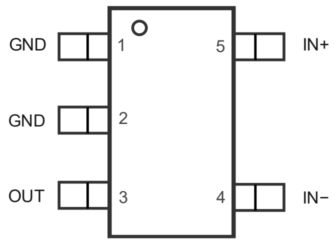
Date	Revision	Notes
2022-03	Preliminary	Initial release
2022-06	Rev.A.0	Released Version

Pin Configuration and Functions

TPA183

SOT23-5 Package

Top View



Pin Functions

Pin		I/O	Description
No.	Name		
1	GND	–	Ground
2	GND	–	Ground
3	OUT	OUT	Amplifier Output. The voltage range extends to within mV of each supply rail.
4	IN-	IN	Inverting Input of the Amplifier. Connect to the load side of the shunt resistor.
5	IN+	IN	Non-Inverting Input of Amplifier. Connect to the power side of the shunt resistor. IN+ is also the power supply pin, the operating supply voltage is internally connected to IN+. The voltage range on this pin for power supply application is 2.7 V to 30 V.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
Input Voltage	IN+, IN−(2)	GND − 0.3	42	V
Output Voltage	OUT(2)	GND − 0.3	(IN+) + 0.3	V
T_J	Maximum Junction Temperature		150	°C
T_A	Operating Temperature Range	−55	150	°C
T_{STG}	Storage Temperature Range	−65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) Input voltage may exceed the voltage shown if the current at that terminal is limited to 10 mA

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001(1)	±2	kV
CDM	Charged-Device Model ESD	ANSI/ESDA/JEDEC JS-002(2)	±2	kV

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
IN	IN+, IN−	2.7		30	V

Thermal Information

Package Type	$θ_{JA}$	$θ_{JC}$	Unit
5-Pin SOT23	227	80	°C/W

Electrical Characteristics

All test conditions: T_A = +25°C, V_{SENSE} = V_{IN+} − V_{IN-}, V_{IN+} = 12 V, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
INPUT						
V_{OS}	Input Offset Voltage	V_{CM} = 5 V		55	±250	μV
V_{OS} TC	Input Offset Voltage Drift	−40°C to 125°C		0.1	0.5	μV/°C
V_{CM}	Common-mode Input Range	−40°C to 125°C	2.7		30	V
CMRR	Common Mode Rejection Ratio	V_{IN+} = 2.7 V to 20 V, V_{SENSE} = 10 mV	95	105		dB
I_B	Input Bias Current	V_{SENSE} = 0 mV		35		μA
NOISE RTI (1)						
e_n	Input Voltage Noise Density	f = 1 kHz		30		nV/√Hz
OUTPUT						
G	Gain	TPA183A1		25		V/V
		TPA183A2		50		V/V
		TPA183A3		100		V/V
		TPA183A4		200		V/V
GE	Gain Error	V_{SENSE} = −5 ~ 5 mV, −40°C to 125°C		±0.1%	±1%	
GE TC	Gain Error vs Temperature	−40°C to 125°C		3	10	ppm/°C
C_{LOAD}	Maxim Capacitive Load	No oscillation		1		nF
V_{OH}	Output Swing from Supply Rail	R_{LOAD} = 10 kΩ to GND, −40°C to 125°C		0.09	0.15	V
V_{OL}	Output Swing from GND	R_{LOAD} = 10 kΩ to GND, −40°C to 125°C		0.01	0.02	V
FREQUENCY RESPONSE						
BW	Bandwidth	C_{LOAD} = 10 pF, TPA183A1		100		kHz
		C_{LOAD} = 10 pF, TPA183A2		48		kHz
		C_{LOAD} = 10 pF, TPA183A3		30		kHz
		C_{LOAD} = 10 pF, TPA183A4		20		kHz
SR	Slew Rate			0.6		V/μs
POWER SUPPLY						
I_Q	Quiescent Current, (IN+)	V_{SENSE} = 0 mV		150	220	μA
TEMPERATURE RANGE						
Operating Range			−40		125	°C

(1) RTI = referred to input.

Typical Performance Characteristics

All test conditions: V_{IN+} = 12 V, T_A = +25°C, unless otherwise noted.

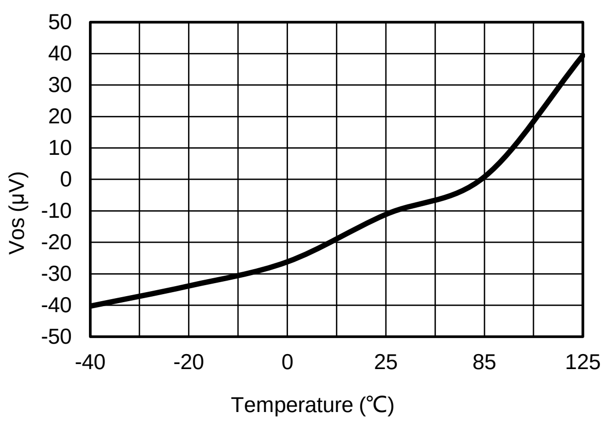


Figure 1. Vos vs. Temperature

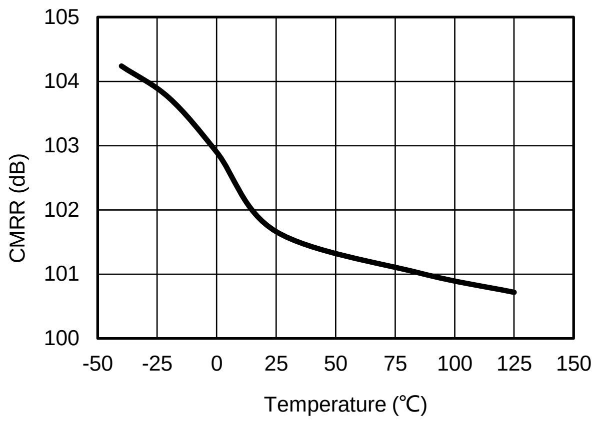


Figure 2. CMRR vs. Temperature

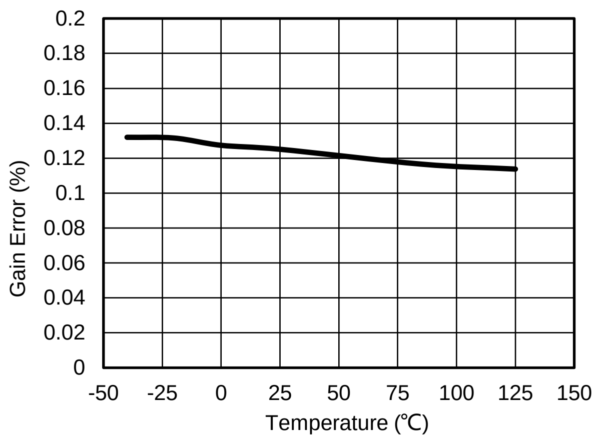


Figure 3. Gain Error vs. Temperature

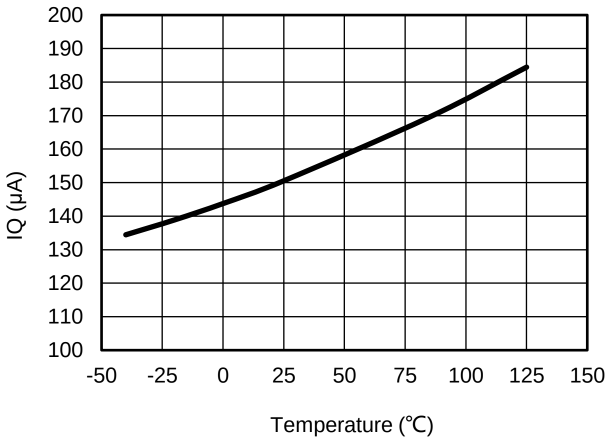


Figure 4. Quiescent Current vs. Temperature

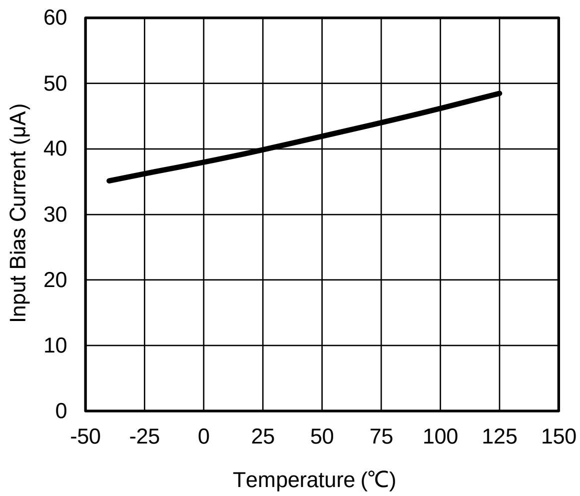


Figure 5. Input Bias Current vs. Temperature

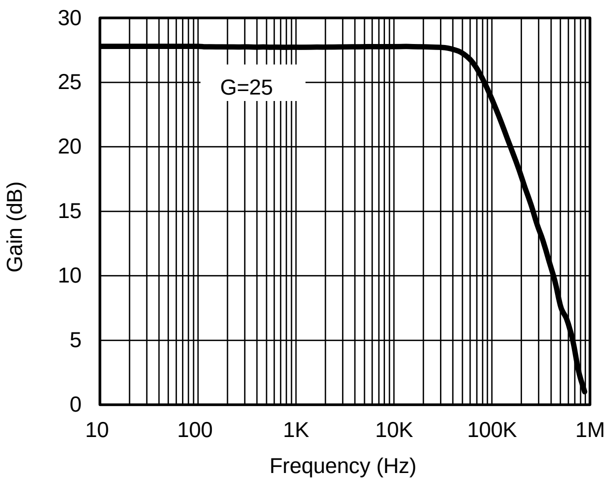


Figure 6. Gain vs. Frequency

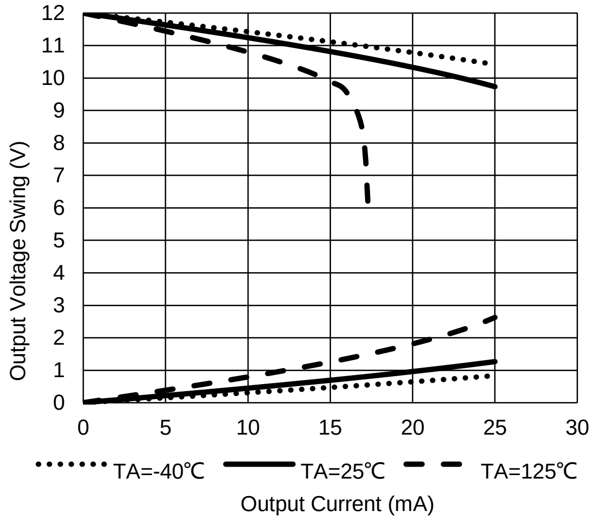


Figure 7. Output Current vs. Temperature

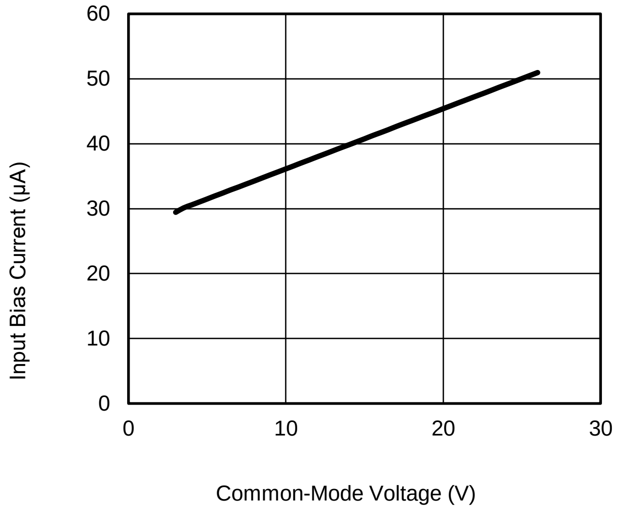


Figure 8. Input Bias Current vs. Common-Mode Voltage

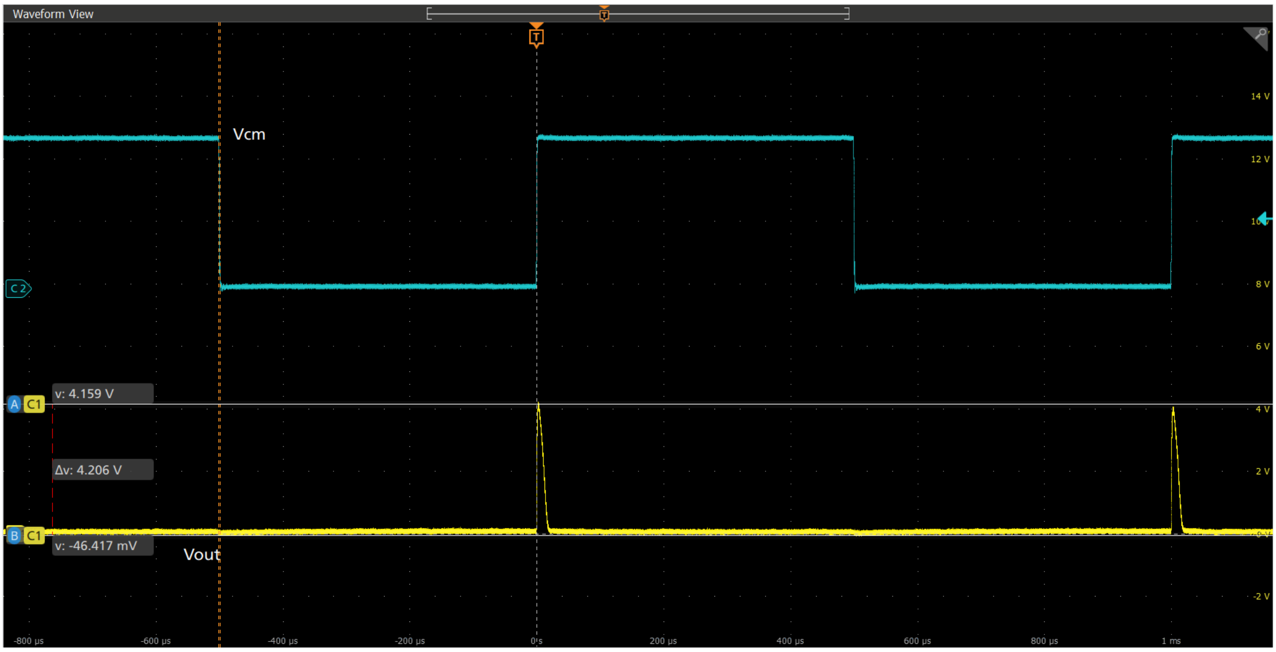


Figure 9. Start-Up Response

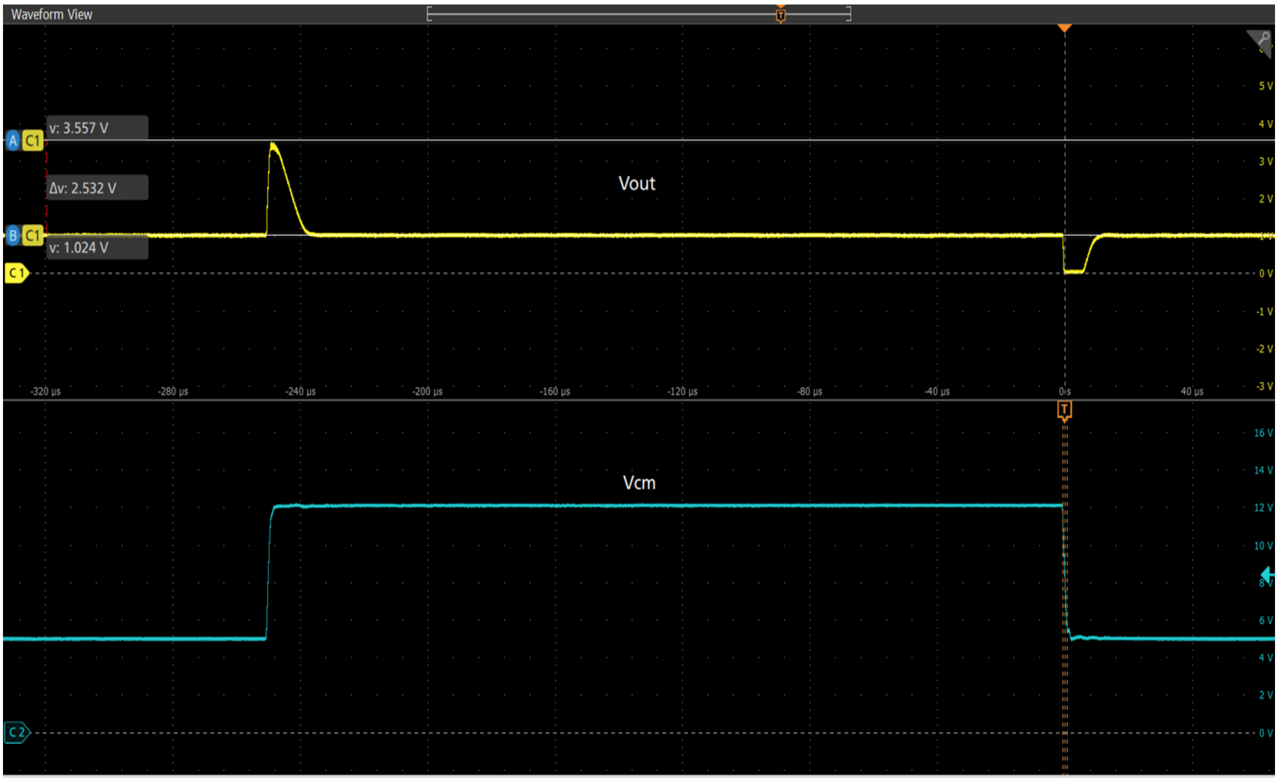


Figure 10. Common-Mode Voltage Transient Response

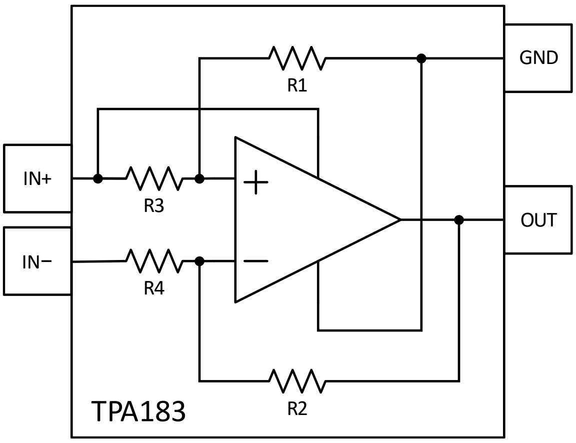
Detailed Description

Overview

The TPA183 family includes 30 V common-mode, zero-drift topology, and unidirectional current-sensing amplifiers that can be used in both low-side and high-side configurations. The device monitors the current through a current-sense resistor and amplifies the voltage across that resistor. The TPA183 features an input common-mode voltage ranging from 2.7 V to 30 V.

Functional Block Diagram

The diagram shows the nominal values for the internal gain setting resistors. The gain accuracy is based on the matching of the four gain resistors which are tightly controlled.



PRODUCT	GAIN	R3 and R4 (kΩ)	R1 and R2 (MΩ)
TPA183A1	25	40	1
TPA183A2	50	20	1
TPA183A3	100	10	1
TPA183A4	200	5	1

Feature Description

Low Offset Voltage and Drift

The zero-drift topology supports high-precision measurements with maximum input offset voltages as low as ±250 μV with a maximum temperature contribution of 0.5 μV/°C over the full temperature range of –40°C to 125°C.

Single-Supply Operation from IN+ and Gain

The current-sense amplifier operates by drawing power from the IN+ pin with a maximum of 220 μA quiescent current. The gain accuracy is based on the matching of the internal gain resistors which are tightly controlled. The TPA183 family has a voltage output and is offered in four gain options: 25 V/V (TPA183A1), 50 V/V (TPA183A2), 100 V/V (TPA183A3), and 200 V/V (TPA183A4).

Application and Implementation

NOTE

Information in the following applications sections is not part of the 3PEAK's component specification, and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

The TPA183 measures the voltage developed across a current-sensing resistor when the current passes through it. The TPA183 does not have a dedicated power supply. Instead, an internal connection to the IN+ pin serves as the power supply for this device. This allows the device to be used in applications where lower voltage or sub-regulated supply rails are not present.

Typical Application

Figure 11 shows the typical application schematic.

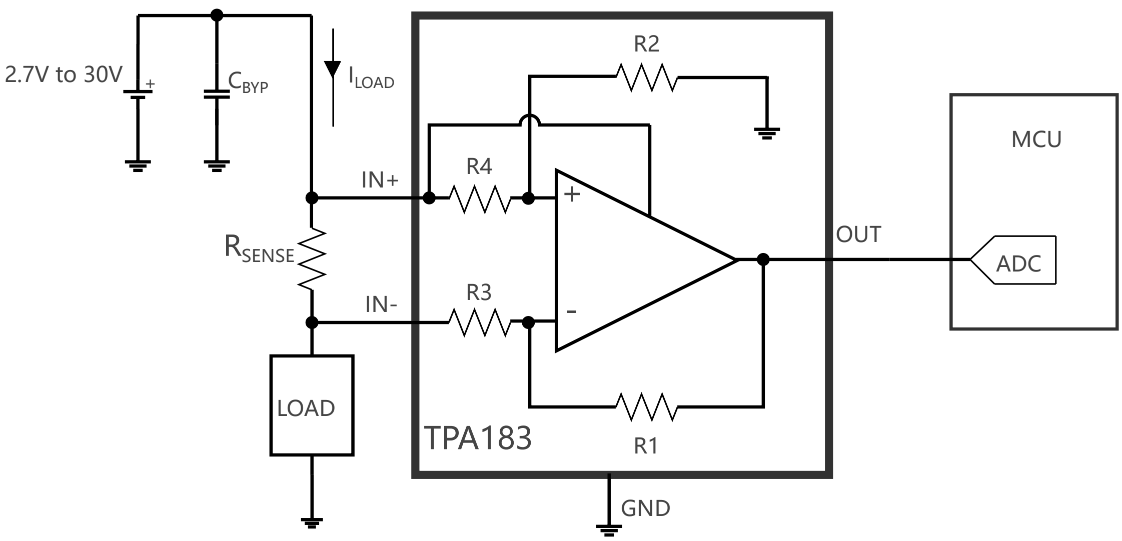


Figure 11. Application Schematic

Basic connections

The basic connections above show the typical high-side current-sense circuit. The TPA183 only supports unidirectional mode because the IN+ pin should be connected to the supply voltage. IN+ and IN− should be connected as closely as possible to R_{SENSE} to minimize any resistance in series with the shunt resistor.

Connecting a power-supply bypass capacitor CBYP close to the device on IN+ is required to reject power-supply noise.

Accuracy and R_{SENSE} Selection

The high R_{SENSE} value can increase the accuracy of the current-sense amplifier. A higher R_{SENSE} value maximizes the differential input signal for a given amount of current and reduces the error contribution of the offset voltage because offsets are less significant when the sense voltage is larger.

Without any limitation in a given application, use the linear equation to calculate the total error in the linear region: V_{OUT} = (gain x V_{OS}) ± (gain ± GE) x (I_{SENSE} x R_{SENSE}), where V_{OS} is the input offset voltage and GE is the gain error of the current-sense amplifier, I_{SENSE} is the current flow through R_{SENSE}.

The power dissipation on R_{SENSE} is I^2R, which should be considered when choosing the resistor value and its power dissipation budget. Also, the current-sense resistor's value might drift if it is allowed to heat up excessively. For the TPA183, V_{OS} = ±250 μV max. The low offset voltage allows the use of small sense resistors to reduce power dissipation and reduce hot spots.

The V_{OUT} is limited by the power-supply voltage at the IN+ pin for a given application. The positive and negative output swing as specified by V_{OH} and V_{OL} in the datasheet. The input V_{SENSE} full scale should be limited by V_{OUT}/GAIN, where V_{SENSE} is I_{SENSE} x R_{SENSE}. The equation provides the limit of R_{SENSE}: V_{OL} < I_{SENSE} x R_{SENSE} x GAIN < V_{OH}, where I_{SENSE} can be the maximum current or the minimum current.

Layout

Layout Guideline

Because of the high currents that flow through R_{SENSE}, take care to eliminate parasitic trace resistance from causing errors in the sense voltage. Either use a four-terminal current-sense resistor or use Kelvin (force and sense) PCB layout techniques.

Place R_{SENSE} as closely as possible to IN+/IN− minimize any resistance in series with the shunt resistor.

Place the bypass capacitor as close as possible to the IN+ pin and ground pins.

Layout Example

Figure 12 shows the location of external components as they appear on the TPA183 Layout Example.

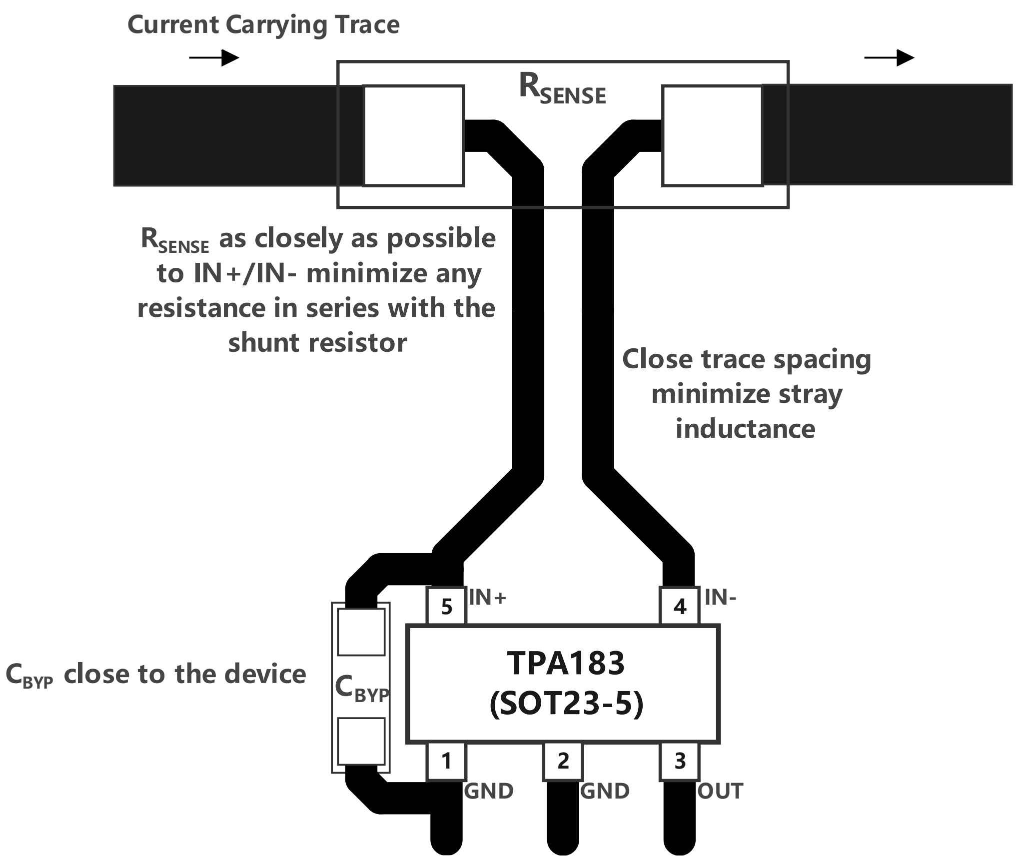
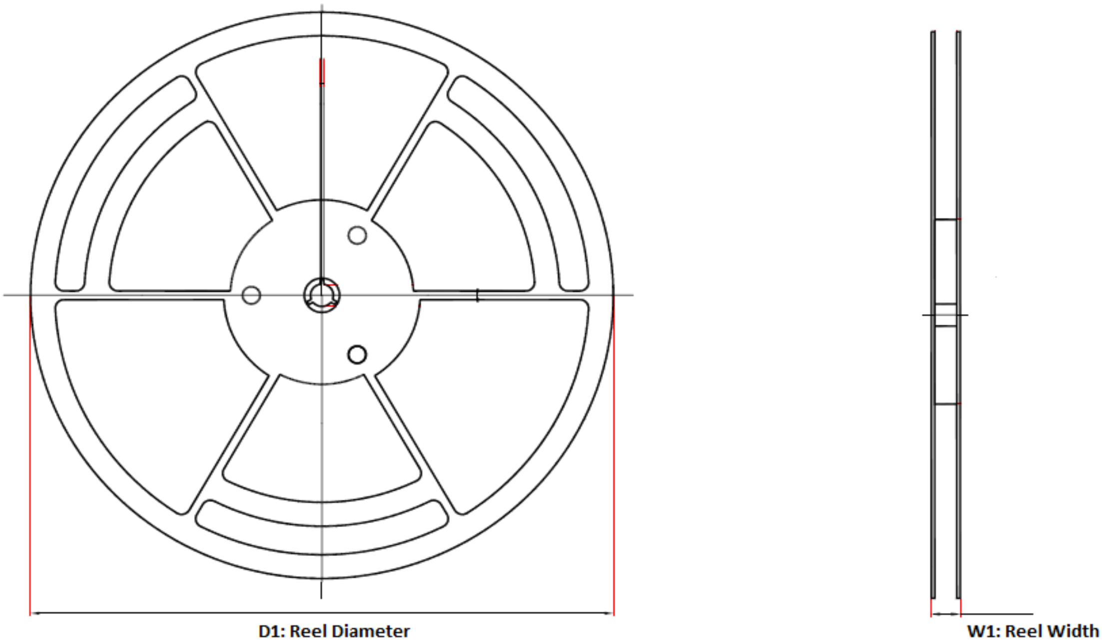
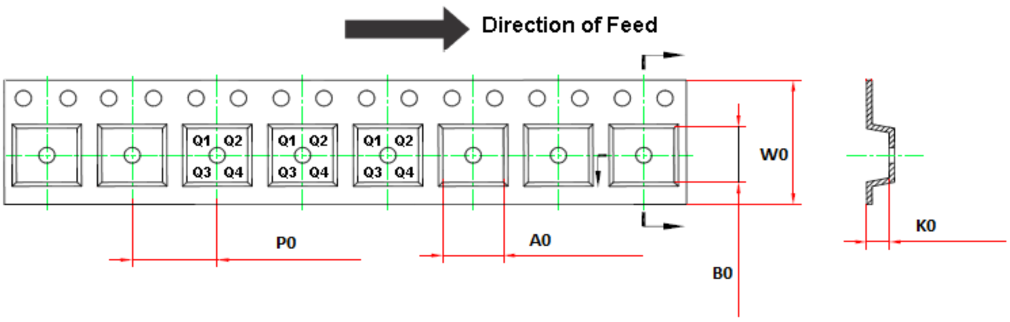


Figure 12. TPA183 Layout Example

Tape and Reel Information

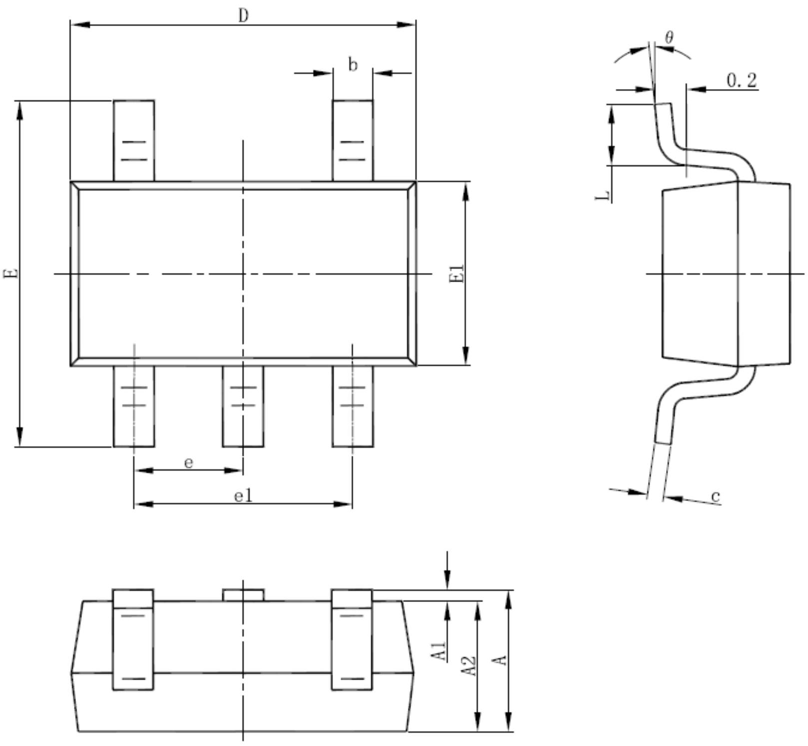




Order Number	Package	D1 (mm)	A0 (mm)	K0 (mm)	W0 (mm)	W1 (mm)	B0 (mm)	P0 (mm)	Pin1 Quadrant
TPA183A1-S5TR	SOT23-5	180.0	3.2	1.4	8.0	13.1	3.2	4.0	Q3
TPA183A2-S5TR	SOT23-5	180.0	3.2	1.4	8.0	13.1	3.2	4.0	Q3
TPA183A3-S5TR	SOT23-5	180.0	3.2	1.4	8.0	13.1	3.2	4.0	Q3
TPA183A4-S5TR	SOT23-5	180.0	3.2	1.4	8.0	13.1	3.2	4.0	Q3

Package Outline Dimensions

SOT23-5



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E1	1.500	1.700	0.059	0.067
E	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA183A1-S5TR	−40 to 125°C	SOT23-5	3A1	3	Tape and Reel, 3,000	Green
TPA183A2-S5TR	−40 to 125°C	SOT23-5	3A2	3	Tape and Reel, 3,000	Green
TPA183A3-S5TR [Note 1]	−40 to 125°C	SOT23-5	3A3	3	Tape and Reel, 3,000	Green
TPA183A4-S5TR [Note 1]	−40 to 125°C	SOT23-5	3A4	3	Tape and Reel, 3,000	Green

Note 1: For future products, contact the 3PEAK factory for more information and samples.

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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