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)
  - 0.5-μV/°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 (Max)
- Rail-to-Rail Output
- Package: SOT23-5
- Industrial Operation Range: −40°C to 125°C
- ESD Rating: Robust 2-kV HBM, 2-kV CDM

Applications

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

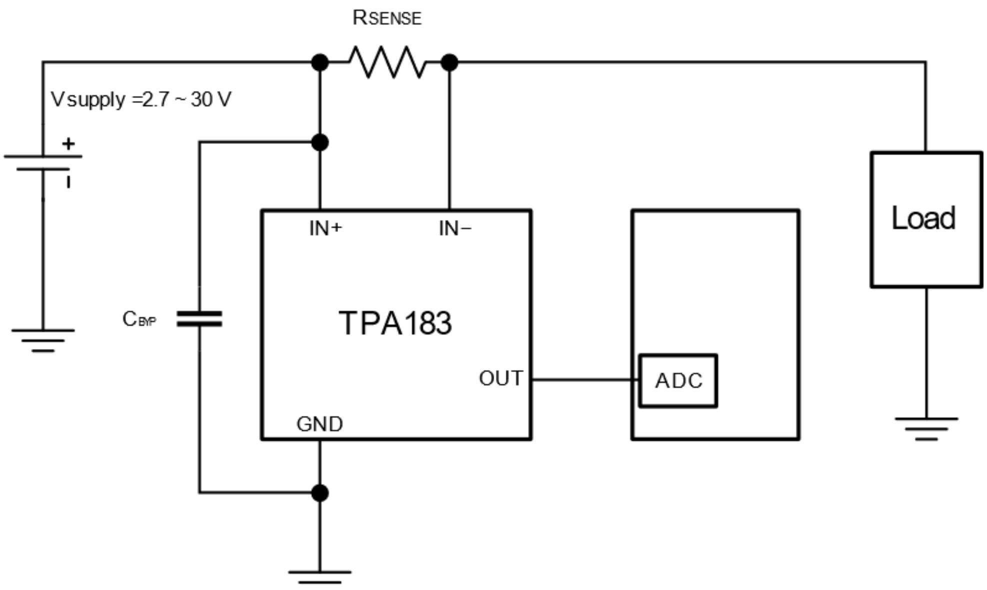
Description

The TPA183 is a series of zero-drift, unidirectional current sense amplifiers that 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 the full-scale current sensing with maximum drops across the shunts to be as low as 10 mV.

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

The TPA183 series is specified from −40°C to +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
TPA183FA1-S5TR	25	SOT23-5	Tape and Reel, 3,000	3A1
TPA183A2-S5TR	50	SOT23-5	Tape and Reel, 3,000	3A2
TPA183A3-S5TR (1)	100	SOT23-5	Tape and Reel, 3,000	3A3
TPA183A4-S5TR (1)	200	SOT23-5	Tape and Reel, 3,000	3A4

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

Table of Contents

Revision History

Date	Revision	Notes
2022-03-01	Rev.Pre.0	Pre-released version.
2022-06-01	Rev.A.0	Initial version.
2024-11-21	Rev.A.1	• Updated the datasheet format. • Added a new orderable part number TPA183FA1-S5TR which features different Pin1 Quadrant.

Pin Configuration and Functions

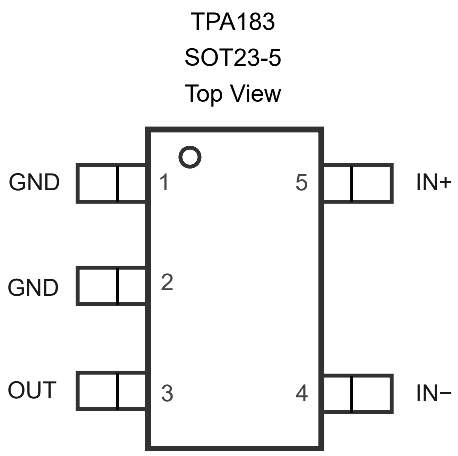


Table 1. Pin Functions

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

Specifications

Absolute Maximum Ratings (1)

Symbol	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) The input voltage may exceed the voltage shown above 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
SOT23-5	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 to 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.

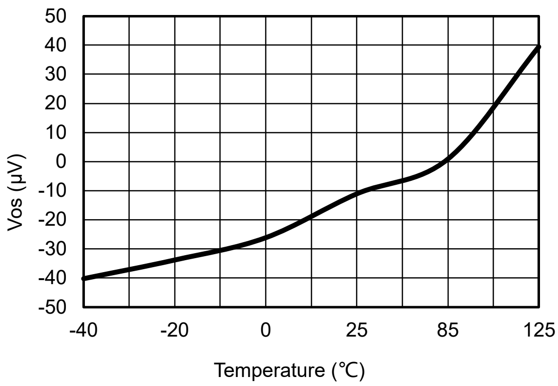


Figure 1. V_{OS} vs. Temperature

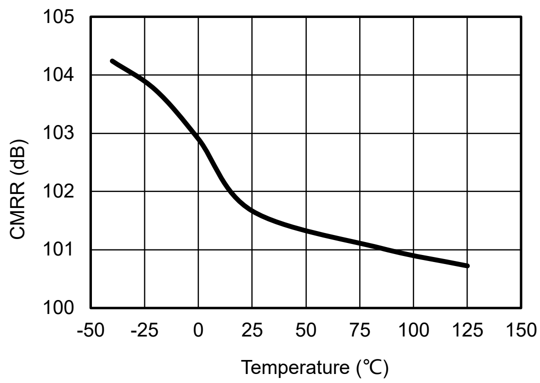


Figure 2. CMRR vs. Temperature

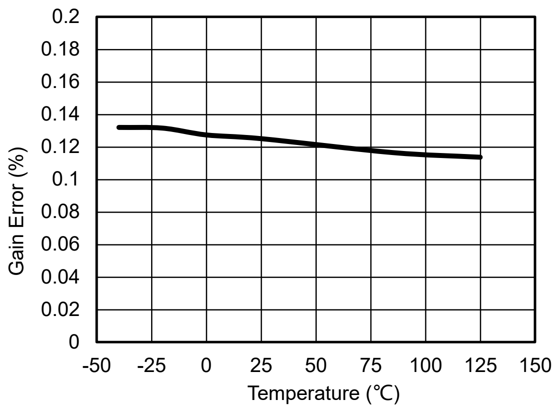


Figure 3. Gain Error vs. Temperature

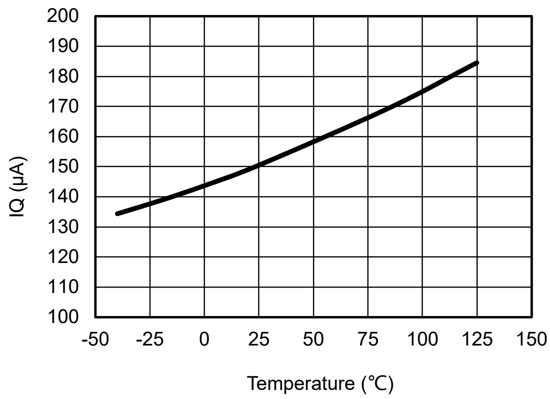


Figure 4. Quiescent Current vs. Temperature

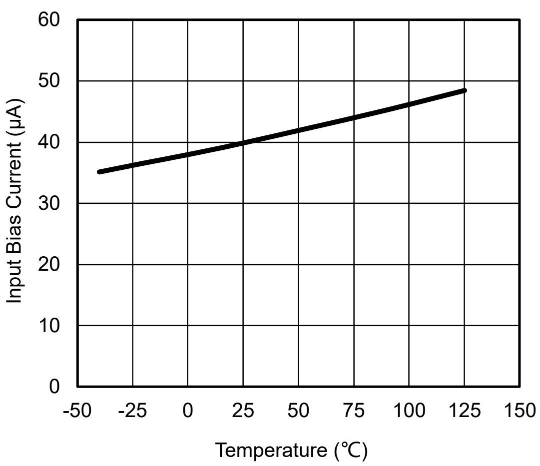


Figure 5. Input Bias Current vs. Temperature

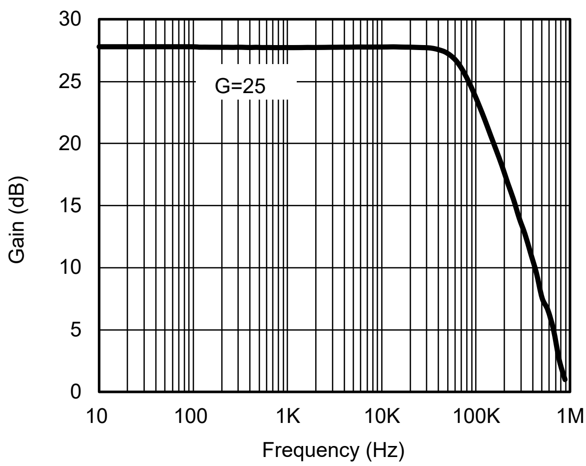


Figure 6. Gain vs. Frequency

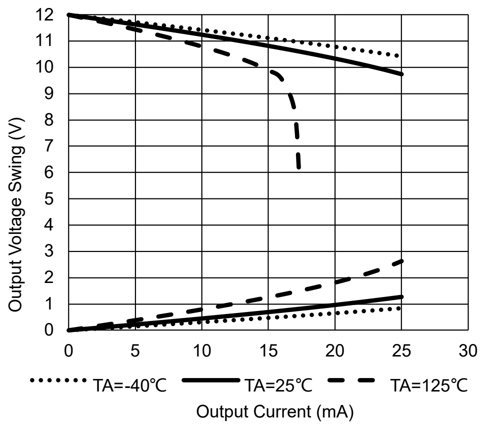


Figure 7. Output Current vs. Temperature

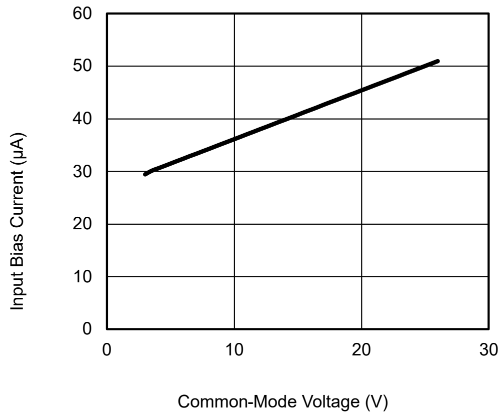


Figure 8. Input Bias Current vs. Common-Mode Voltage

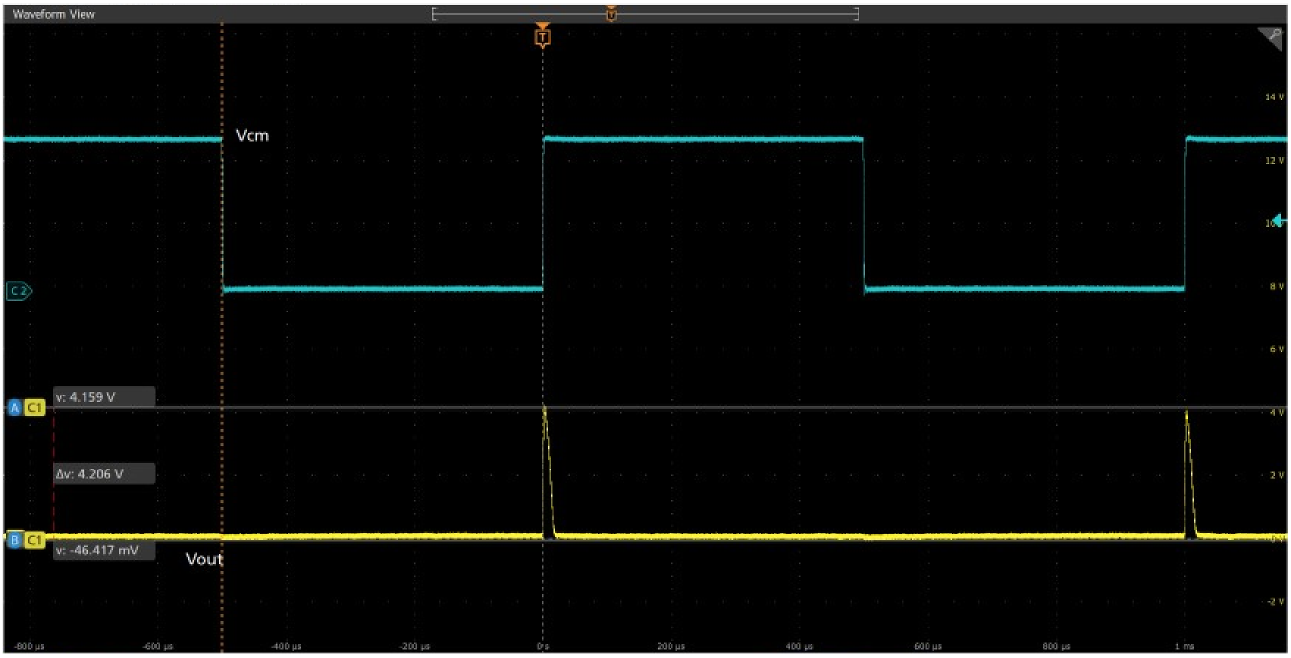


Figure 9. Start-Up Response

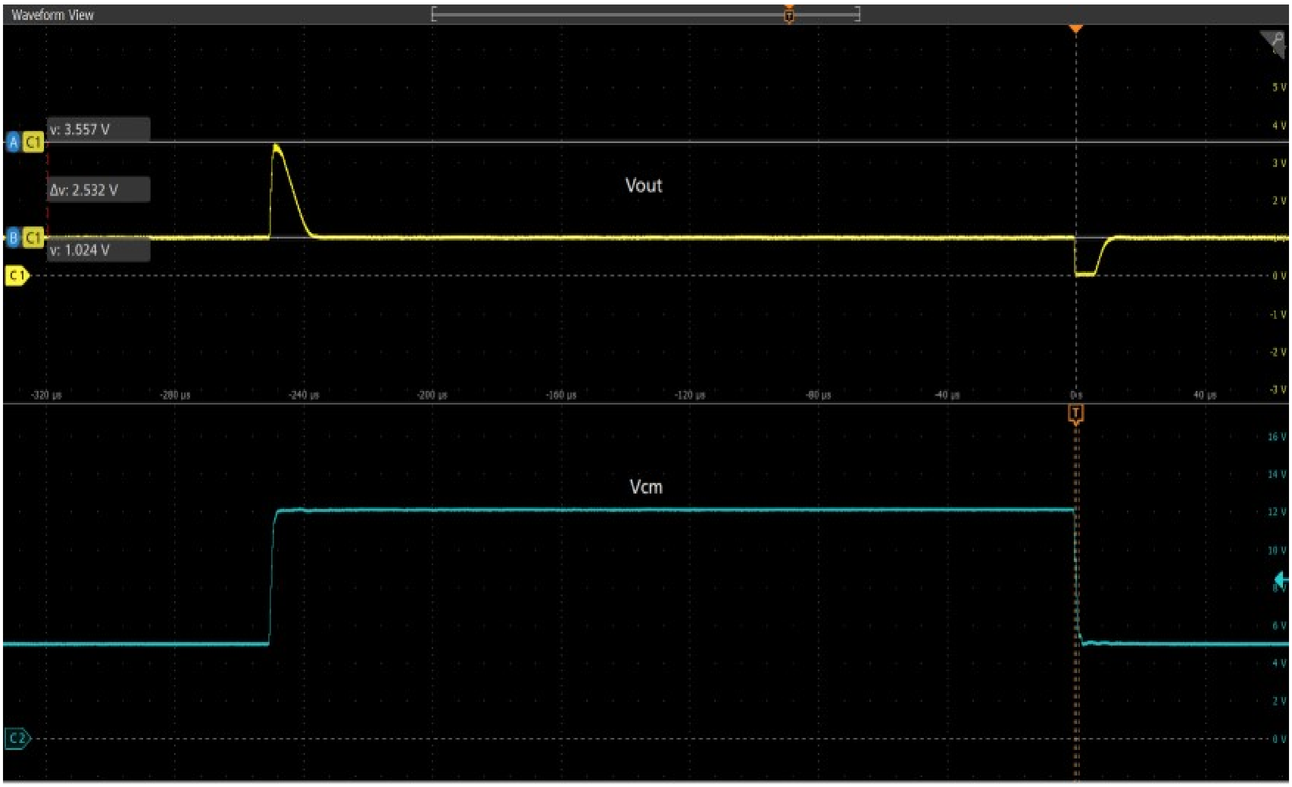


Figure 10. Common-Mode Voltage Transient Response

Detailed Description

Overview

The TPA183 is a series of 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 TPA183 series monitors the current through a current-sense resistor, and amplifies the voltage across that resistor. The TPA183 series features an input common-mode voltage ranging from 2.7 V to 30 V.

Functional Block Diagram

Figure 11 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.

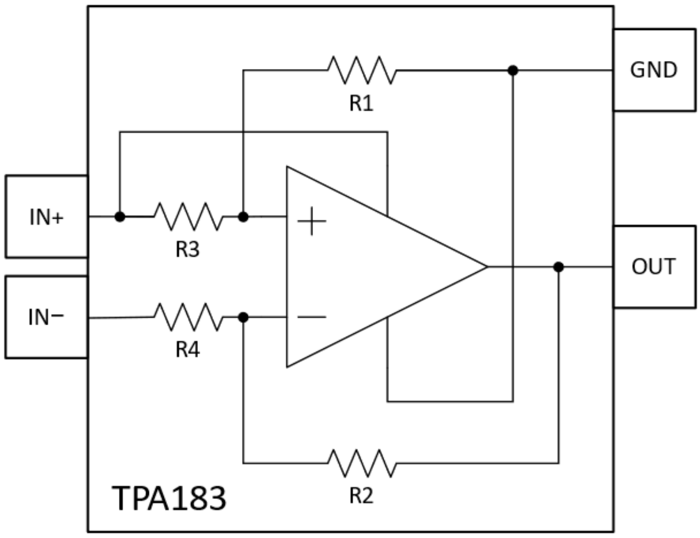


Figure 11. Functional Block Diagram

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 a maximum input offset voltage as low as ±250 μV and a maximum temperature contribution of 0.5 μV/°C over the full temperature range from −40°C to 125°C.

Single-Supply Operation from IN+ and Gain

The current-sense amplifiers operate by drawing power from the IN+ pin with a maximum quiescent current of 220 µA. The gain accuracy is based on the matching of the internal gain resistors which are tightly controlled. The TPA183 series 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 application 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 series measures the voltage developed across a current-sensing resistor when the current passes through it. The TPA183 series does not have a dedicated power supply. Instead, an internal connection to the IN+ pin serves as the power supply for the devices. This allows the series to be used in applications where lower voltage or sub-regulated supply rails are not present.

Typical Application

Figure 12 shows the typical application schematic.

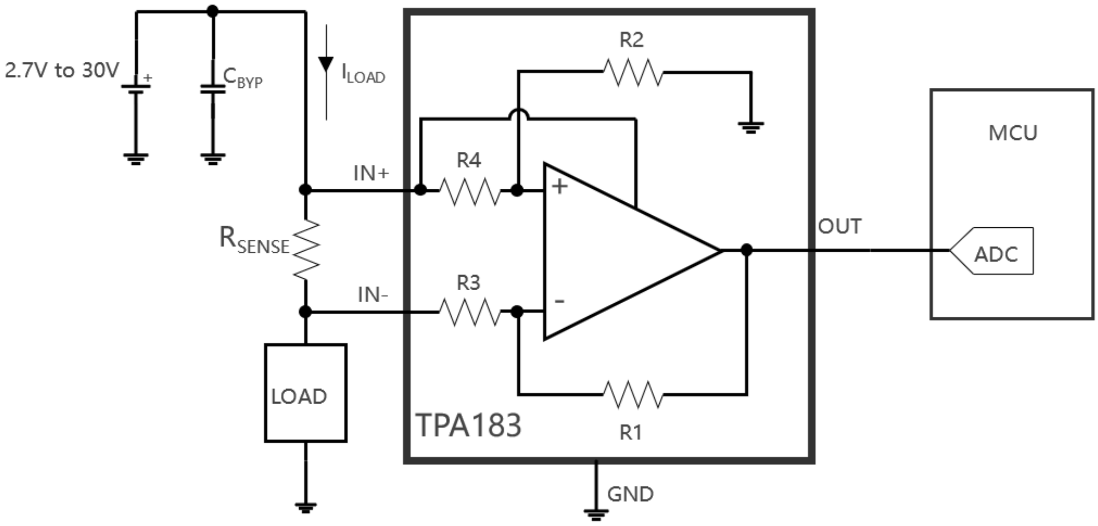


Figure 12. Application Schematic

Basic Connections

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

Connecting a power-supply bypass capacitor, C_{BYP}, close to the device on IN+ is required to prevent the power-supply noise.

Accuracy and R_{SENSE} Selection

A 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 the offset is 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 × V_{OS}) ± (Gain ± GE) × (I_{SENSE} × R_{SENSE}), where V_{OS} is the input offset voltage, GE is the gain error of the current-sense amplifier, and 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 value of the resistor might drift if it is allowed to heat up excessively. For the TPA183 series, V_{OS} is ±250 μV (max). The low offset voltage allows the use of small sense resistors to reduce power dissipation and hot spots.

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

Layout

Layout Guideline

Because of the high currents that flow through R_{SENSE}, take care to eliminate the 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 close as possible to IN+/IN− to minimize any resistance in series with the shunt resistor.

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

Layout Example

Figure 13 shows the location of external components as they appear on the TPA183 Layout Example.

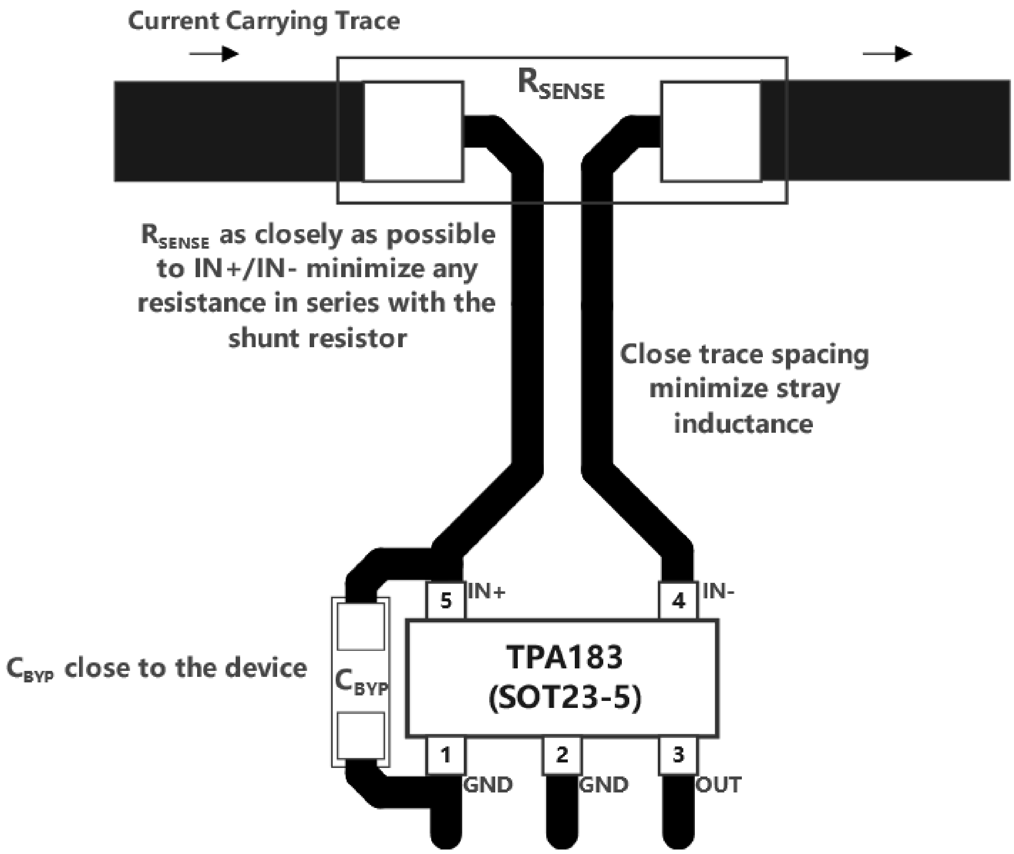
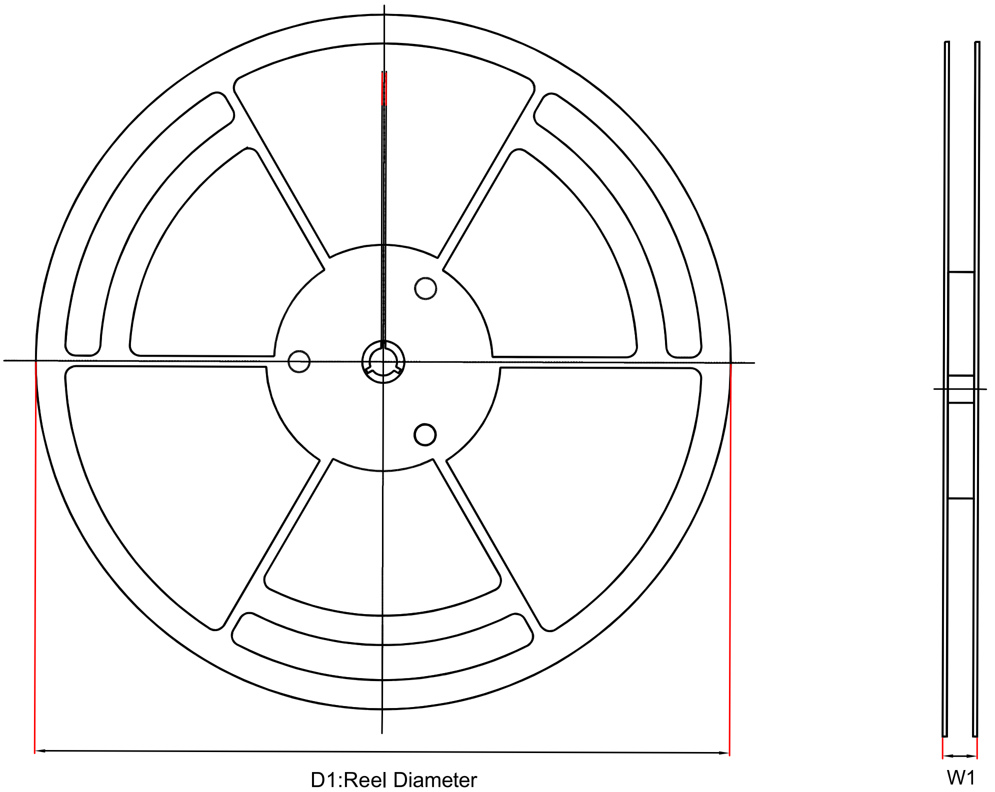
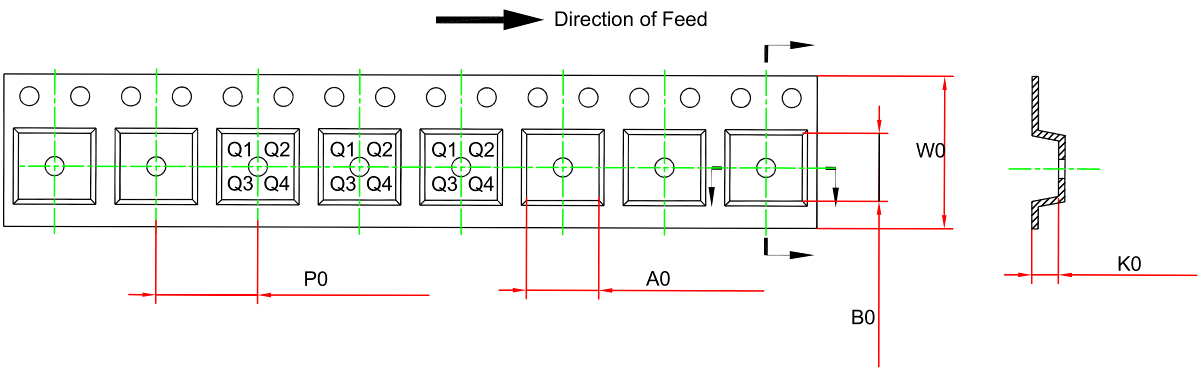


Figure 13. TPA183 Layout Example

Tape and Reel Information





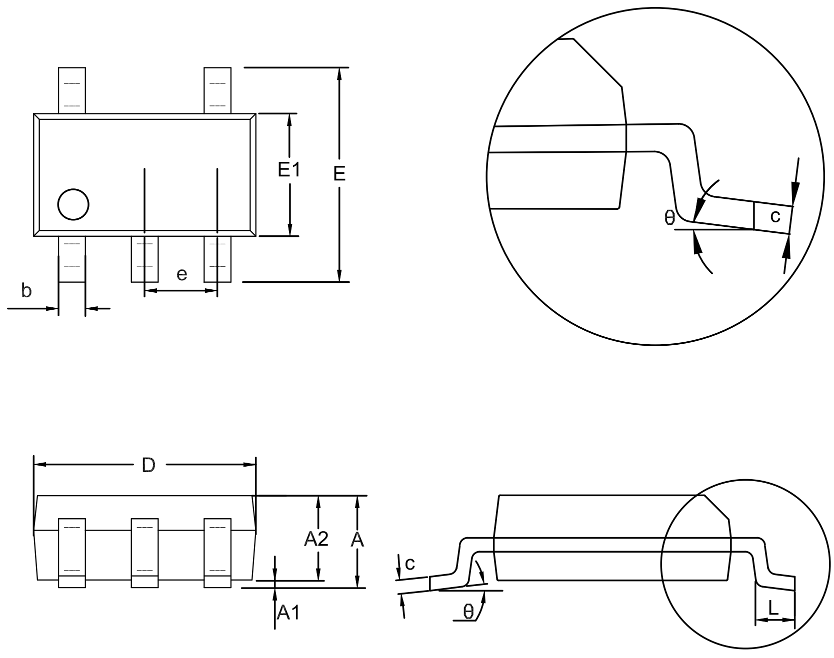
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA183A1-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA183FA1-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q2
TPA183A2-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA183A3-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA183A4-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3

(1) The value is for reference only. Contact the 3PEAK factory for more information.

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037 BSC	
L	0.300	0.600	0.012	0.024
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

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, 3000	Green
TPA183FA1-S5TR	−40 to 125°C	SOT23-5	3A1	3	Tape and Reel, 3000	Green
TPA183A2-S5TR	−40 to 125°C	SOT23-5	3A2	3	Tape and Reel, 3000	Green
TPA183A3-S5TR (1)	−40 to 125°C	SOT23-5	3A3	3	Tape and Reel, 3000	Green
TPA183A4-S5TR (1)	−40 to 125°C	SOT23-5	3A4	3	Tape and Reel, 3000	Green

(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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