High-Side Variable Gain Current Sense Amplifier

Features

- High-Side Unidirectional Current Sense Amplifier
- Wide Common-Mode Input Range: 3 V to 60 V
- Wide Supply Voltage Range: 3 V to 60 V
- Independent Supply and Input Voltages
- Variable Gain Set by Single Resistor
- Low Quiescent Current: 50 μA (Typical)
- Wide Temperature Range: −40°C to 125°C
- SOT23-5 Package

Applications

- Current Measurement
  - Monitors, Computers
- Telecom Equipment
- Power Management
- Servers

Description

The TPA127 is a high-side, unidirectional current-sensing amplifier with a current output. Although designed for current shunt measurement, the device is also well suited for measurement and level conversion in creative applications.

The device converts the differential input voltage to a current output by its transconductance characteristic. The output current flows through the external load resistor and generates the output voltage. The gain between the output voltage and differential input voltage can be set from 1 to over 100 by the product of the external load resistor and transconductance.

The supply and input voltages are independent and operate from 3 V to 60 V. The device is available in the SOT23-5 package. Its operating temperature range is from −40°C to +125°C.

Typical Application Circuit

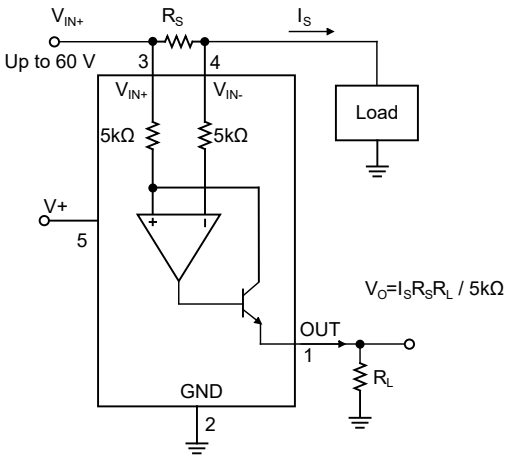


Table of Contents

Revision History

Date	Revision	Notes
2024-09-17	Rev.A.0	Initial version.
2024-12-18	Rev.A.1	The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged. • Updated the Tape and Reel Information.

Pin Configuration and Functions

TPA127
SOT23-5
Top View

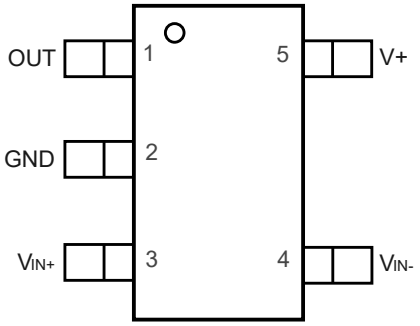


Table 1. Pin Functions

Pin No.	Name	I/O	Description
1	OUT	Analog Output	Output current
2	GND	—	Ground
3	V_{IN+}	Analog Input	Positive input voltage
4	V_{IN-}	Analog Input	Negative input voltage
5	V+	Analog Input	Power supply voltage

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
V+	Supply Voltage	–0.3	75	V
V_{IN}	Input Common-Mode Voltage	–0.3	75	V
	Sense Voltage, V_{SENSE} = Input Differential Voltage, (IN+) − (IN−)	−10	10	V
V_O	Output Voltage	−0.3	75	V
	Input Current into Any Pin	−10	10	mA
T_A	Operating Temperature Range	−40	125	°C
T_J	Maximum Junction Temperature		150	°C
T_{STG}	Storage Temperature Range	−65	150	°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.

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)	1.5	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
V+	Supply Voltage	3		60	V
V_{SENSE}	Full-Scale Sense Voltage			2	V
V_{IN}	Input Voltage	3		60	V
T_A	Operating Temperature Range	−40	25	125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W

Electrical Characteristics

All test conditions: T_A = +25°C, V+ = 3.3 V, V_{IN+} = 12 V, V_{SENSE} = V_{IN+} − V_{IN-} = 1mV, and R_L = 120 kΩ, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Input						
CMRR	Common-Mode Rejection Ratio	V_{SENSE} = 50 mV, V_{IN+} = 3 V to 60 V	90			dB
V_{OS}	Input Offset Voltage	T_A = 25°C		±0.3	±1.8	mV
		T_A = −40°C to 125°C			±2.4	mV
V_{OS} TC	Offset Voltage Drift (1)	T_A = −40°C to 125°C		1.5		μV/°C
PSRR	Power Supply Rejection Ratio	V_{SENSE} = 50 mV, V_{IN+} = 3 V to 60 V	90			dB
I_B	Input Bias Current (2)	T_A = 25°C		42		μA
		T_A = −40°C to 125°C			50	μA
Output						
g_m	Transconductance	V_{SENSE} = 10 mV to 150 mV, T_A = 25°C	196		204	μA/V
		V_{SENSE} = 10 mV to 150 mV, T_A = −40°C to 125°C	194		205	μA/V
g_m TC	Transconductance Drift (1)	T_A = −40°C to 125°C		6		nS/°C
NE	Nonlinearity Error	V_{SENSE} = 10 mV to 150 mV			±0.1	%
	Total Output Error	V_{SENSE} = 100 mV, T_A = 25°C			±2.5	%
		V_{SENSE} = 100 mV, T_A = −40°C to 125°C			±3.3	%
	Output Capacitance			43		pF
	Voltage Output Swing	To power supply voltage, V+		(V+) + 0.6		V
		To input voltage, V_{IN+}			V_{IN+}	V
Frequency Response						
BW	Bandwidth	R_{Load} = 5 kΩ		333		kHz
		R_{Load} = 120 kΩ		26.8		kHz
	Setting Time (1)	To 0.1%, R_{Load} = 5 kΩ		6		μs
		To 0.1%, R_{Load} = 120 kΩ		100		μs
e_n	Output Current Noise Density (1)			11.4		pA/√Hz
	Total Output Current Noise (1)	BW = 100 kHz		3		nA RMS
Power Supply						
I_Q	Quiescent Current	V_{SENSE} = 0 V, T_A = 25°C		50	60	μA
		V_{SENSE} = 0 V, T_A = −40°C to 125°C			61	μA

(1) Provided by bench tests and design simulation.
(2) The current flowing out of the input pin is considered positive.

Typical Performance Characteristics

All test conditions: T_A = 25°C, V_S = 3.3 V, V_{IN+} = 12 V, R_{Load} = 120 kΩ, unless otherwise noted.

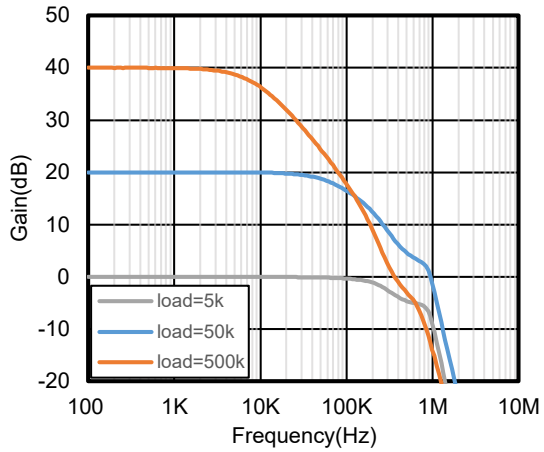


Figure 1. Gain vs. Frequency

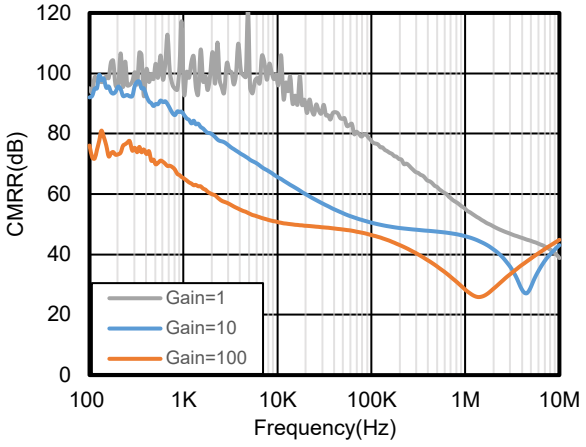


Figure 2. Common-Mode Rejection vs. Frequency

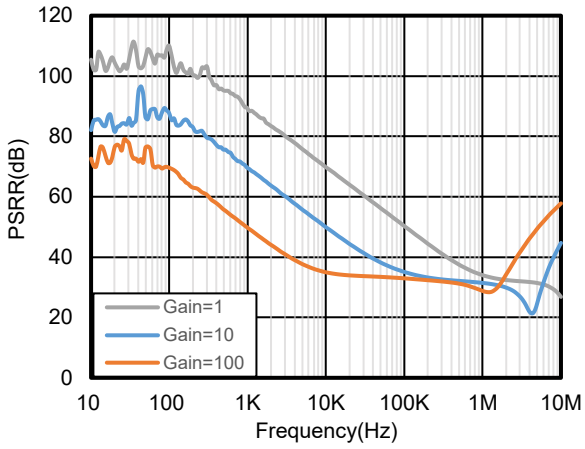


Figure 3. Power-Supply Rejection vs. Frequency

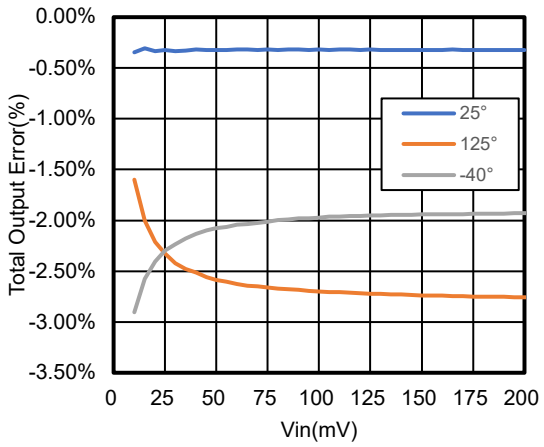


Figure 4. Total Output Error vs. V_{in} (V_{in} = V_{IN+} − V_{IN-})

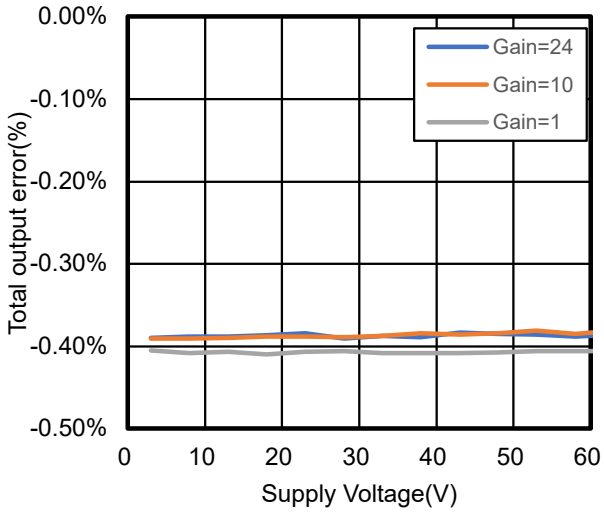


Figure 5. Total Output Error vs. Power-Supply Voltage

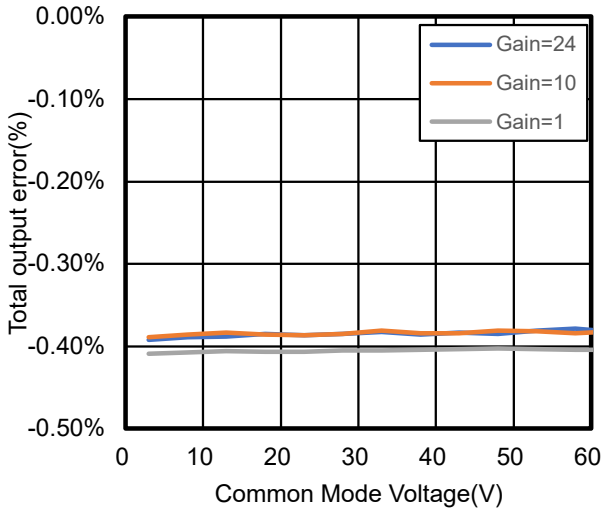


Figure 6. Total Output Error vs. Common-Mode Voltage

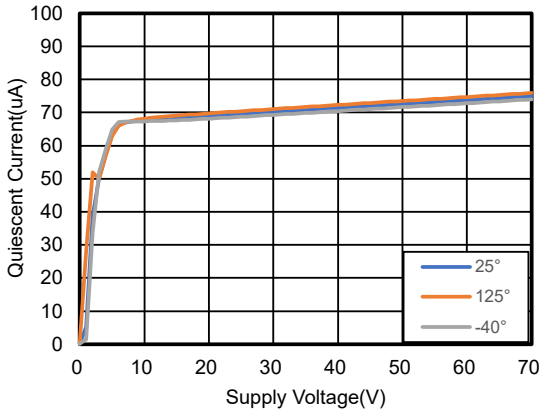


Figure 7. Quiescent Current vs. Supply Voltage

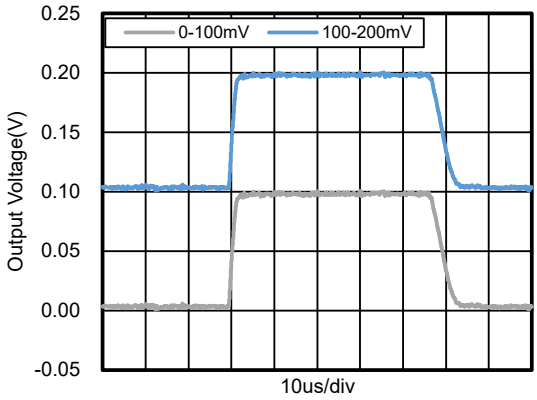


Figure 8. Step Response, Gain = 1

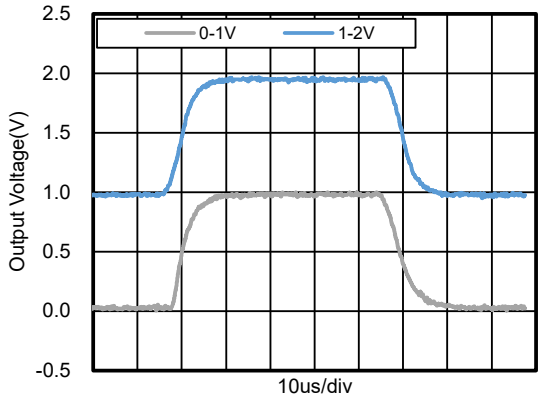


Figure 9. Step Response, Gain = 10

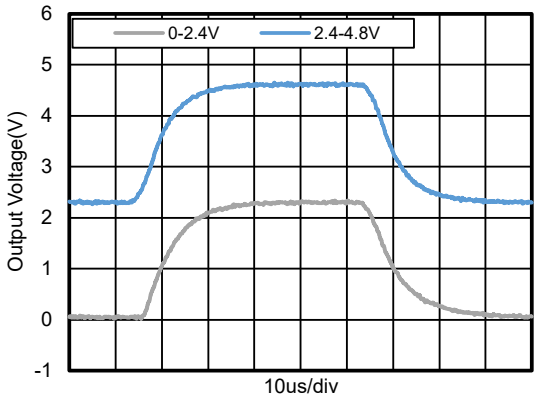


Figure 10. Step Response, Gain = 24

Detailed Description

Overview

The TPA127 device is a high-side, unipolar current-sensing amplifier with a current output. The supply voltage and input voltage are independent and can operate from 3 V to 60 V. The device can work normally even if the input voltage exceeds the supply voltage. Considering the minimum input voltage requirements, the TPA127 is suitable for high-side current-sensing applications.

Functional Block Diagram

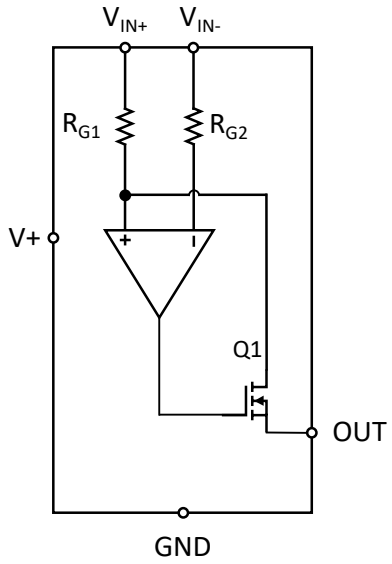


Figure 11. Functional Block Diagram

Feature Description

Output Range

The output voltage keeps linear in the specified range of the differential input voltage and the load resistor. When the differential input voltage is beyond the linear range, the output voltage reaches the maximum value. The maximum output voltage is limited by V_{IN+} and the power supply voltage. The relationship between maximum output voltage ($V_{out\ max}$) and V_{IN+}, V+ depends on either Equation 1 or Equation 2, whichever is lower.

$$V_{out\ max} = (V+) + 0.7\ V \quad (1)$$

$$V_{out\ max} = V_{IN+} \quad (2)$$

Bandwidth

The bandwidth is related to the load resistor. Increase the load resistor to acquire higher gain, which means lower bandwidth. There are several bandwidth curves in different load resistors in Figure 1. Note that the parasitic capacitance parallel to the load resistor forms a pole with the load resistor in frequency characteristics, which means bandwidth loss. Keep the parasitic capacitance low to get no loss in bandwidth.

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

Operation

The TPA127 internal circuit is shown in Figure 12. The load current in applications flows through the shunt resistor and forms a voltage drop as the differential input voltage (V_{dm}) to the chip. V_{dm} is delivered to the voltage on R_{G1} (V_{RG1}) by the TPA127, causing a current flowing into the MOSFET. The load resistor converts this current to output voltage.

$$I_S \cdot R_S = V_{IN+} - V_{IN-} \quad (3)$$

$$I_L = \frac{V_{IN+} - V_{IN-}}{R_{G1}} = g_m \cdot (V_{IN+} - V_{IN-}) \quad (4)$$

Where $g_m = 1 / R_{G1} = 200$ μA/V.

The output voltage is shown in Equation 5.

$$V_{out} = I_L \cdot R_L = g_m \cdot (I_S \cdot R_S) \cdot R_L \quad (5)$$

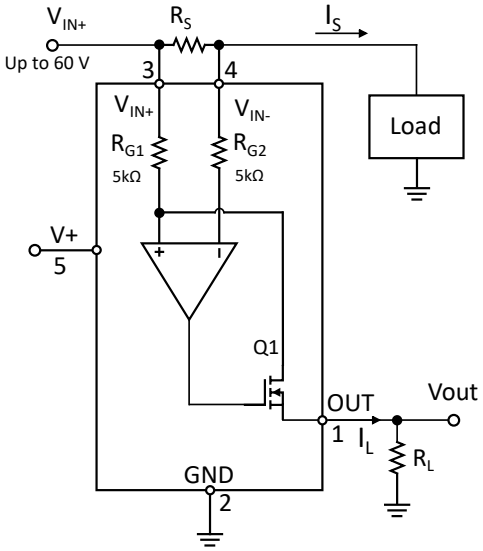


Figure 12. Internal Circuits

Typical Application

Figure 13 shows the typical application schematic.

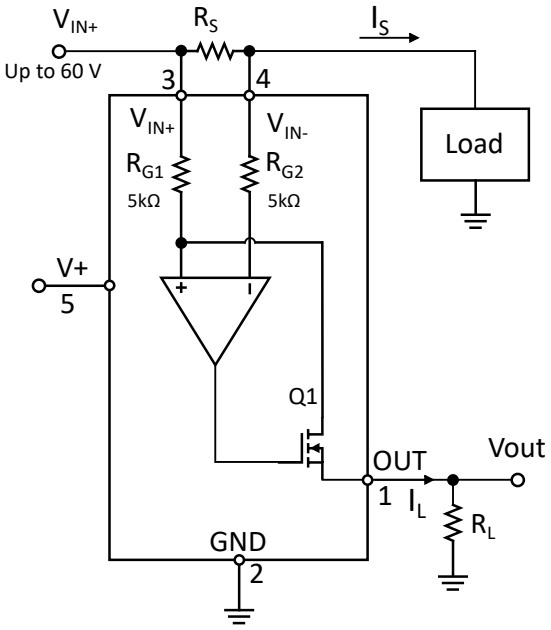


Figure 13. Typical Application Circuit

Output Voltage Detection

An analog-to-digital converter (ADC) is commonly used in output voltage detections. The input impedance of ADCs is parallel to the load resistor. Considering that the output voltage is vulnerable to the load impedance, the effect of the input impedance of ADCs on the output voltage is not negligible. To eliminate such influence on the output voltage, a buffer between the ADCs input and load resistor is added to isolate these two parts. The connection between the TPA127 output and ADC is shown in Figure 14. If the output signal needs filtering, a capacitor is parallel to the load resistor to get an RC filter. The cut-off frequency is $1 / (2\pi R_L C_L)$

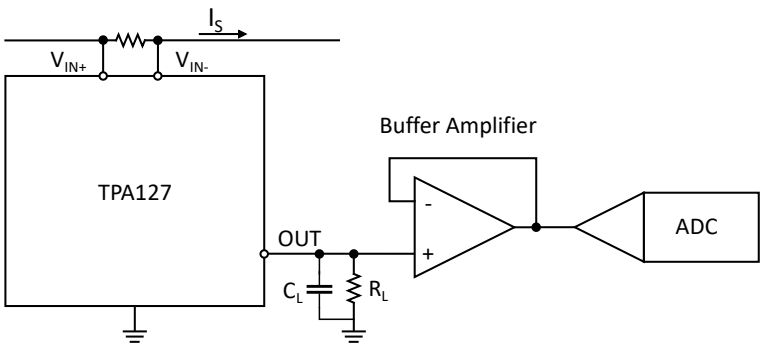


Figure 14. Buffer Output

Offsetting the Output Voltage

Some current sense amplifiers with the REF pin are used to set reference voltage. The TPA127 can realize such an offset function by a voltage divider on the output. Figure 15 illustrates the offset function circuit. The output voltage fluctuates above the offset voltage.

The offset voltage is shown below.

$$V_{offset} = V_B \cdot \frac{R_2}{R_1 + R_2} \quad (6)$$

The equivalent load resistor is R_1 parallel to R_2. The output voltage is determined as below.

$$V_{out} = I_L \cdot R_L + V_{offset} = I_L \cdot \frac{R_1 R_2}{R_1 + R_2} + V_B \cdot \frac{R_2}{R_1 + R_2} \quad (7)$$

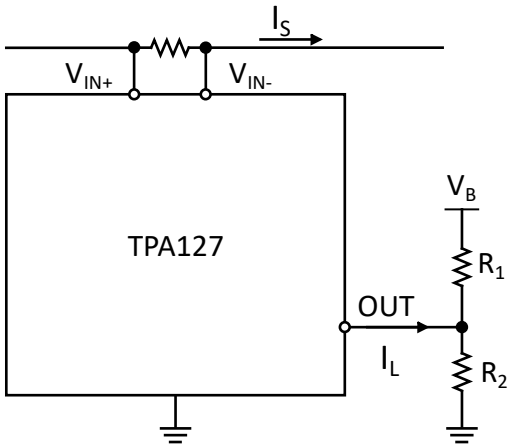
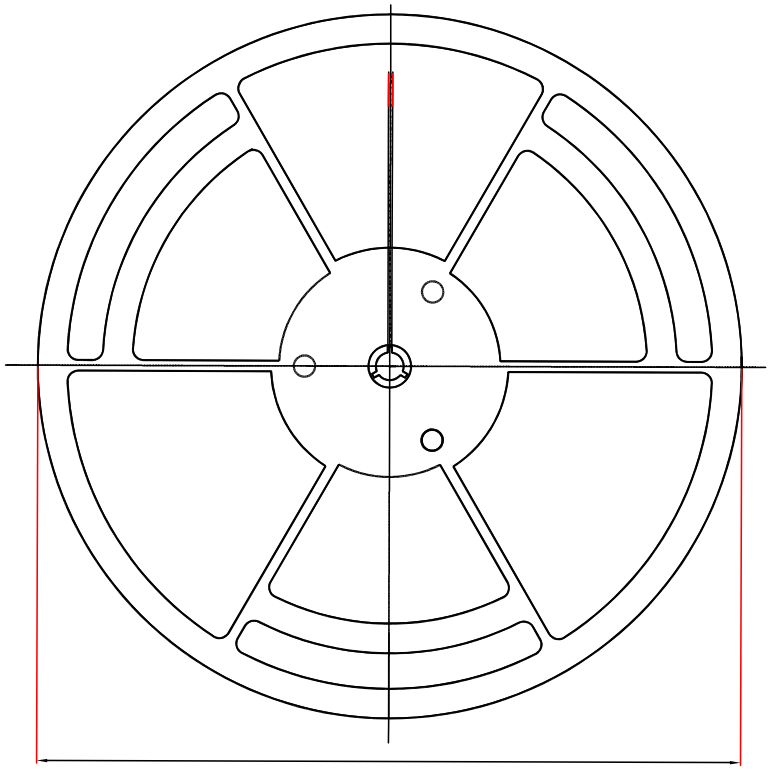


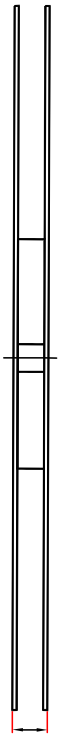
Figure 15. Offset Circuits

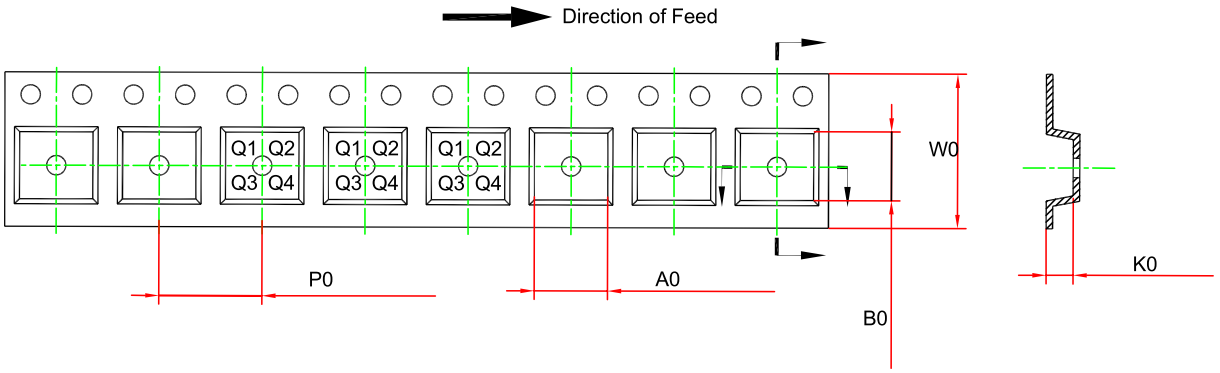
Power Supply Recommendations

To realize better noise decoupling performance on the power supply, the power supply bypass capacitor is placed as close as possible to the supply and the ground terminal. A 0.1-μF capacitor is recommended to use. Additional bypass capacitors can get better noise suppression on the power supply.

Tape and Reel Information







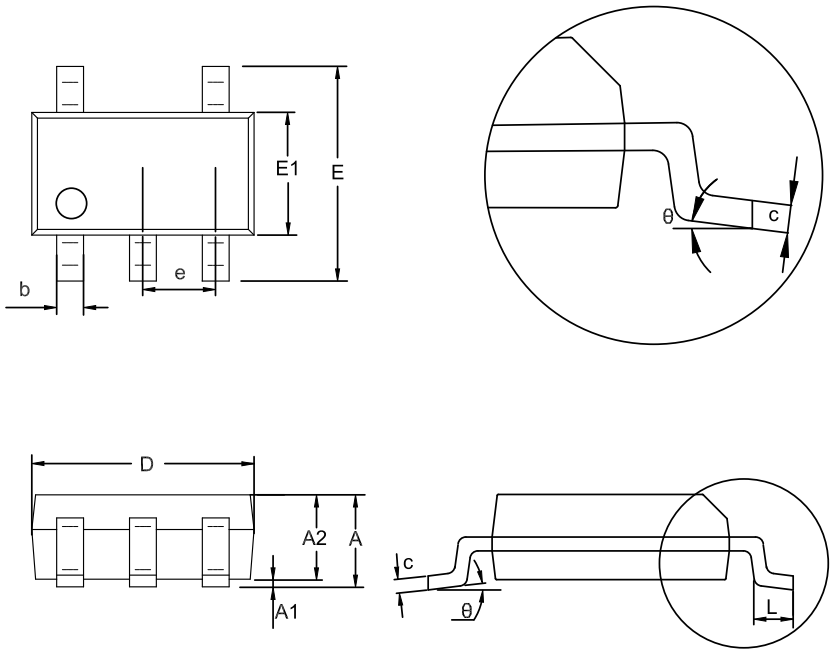
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA127-S5TR-S	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3

(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
TPA127-S5TR-S	−40°C to +125°C	SOT23-5	127	1	Tape and Reel, 3000	Green

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

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